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(54) METHOD OF DEFECT CLOSURE IN ANULUS FIBROSUS

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Related U.S. Application Data

(63) Continuation of application No. 10/055,504, filed on Oct. 25, 2001, which is a continuation-in-part of application No. 09/696,636, filed on Oct. 25, 2000, now Pat. No. 6,508,839, which is a continuation-in-part of application No. 09/642,450, filed on Aug. 18, 2000, now Pat. No. 6,482,235, which is a continuation-in-part of application No. 09/608,797, filed on Jun. 30, 2000, now Pat. No. 6,425,919. Continuation-in-part of application No. 10/020,507, filed on Dec. 11, 2001. Continuation-in-part of application No. 10/194,428, filed on Jul. 10, 2002.

(60) Provisional application No. 60/161,085, filed on Oct. 25, 1999. Provisional application No. 60/172,996, filed on Dec. 21, 1999. Provisional application No. 60/149,490, filed on Aug. 18, 1999. Provisional application No. 60/298,605, filed on Jun. 14, 2001. Provisional application No. 60/311,586, filed on Aug. 10, 2001. Provisional application No. 60/304,545, filed on Jul. 10, 2001.

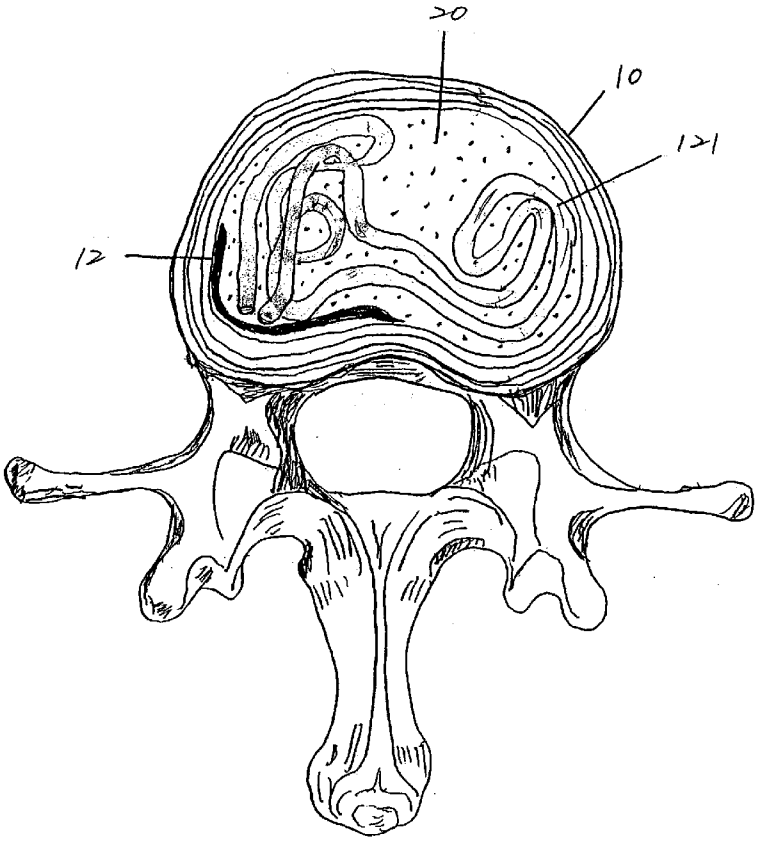
Publication Classification

(51) **Int. Cl.**[7] **A61F 2/44**

(52) **U.S. Cl.** **623/17.16**; 604/907

(57) **ABSTRACT**

Systems for minimally invasive disc augmentation include an anulus augmentation component and a nucleus augmentation component. Both are suited for minimally invasive deployment. The nucleus augmentation component restores disc height and/or replaces missing nucleus pulposus. The anulus augmentation component shields weakened regions of the anulus fibrosis and/or resists escape of natural nucleus pulposus and/or the nucleus augmentation component. Methods and deployment devices are also disclosed. Methods of closing a defect in an anulus fibrosus of an intervertebral disc using a barrier are also provided.



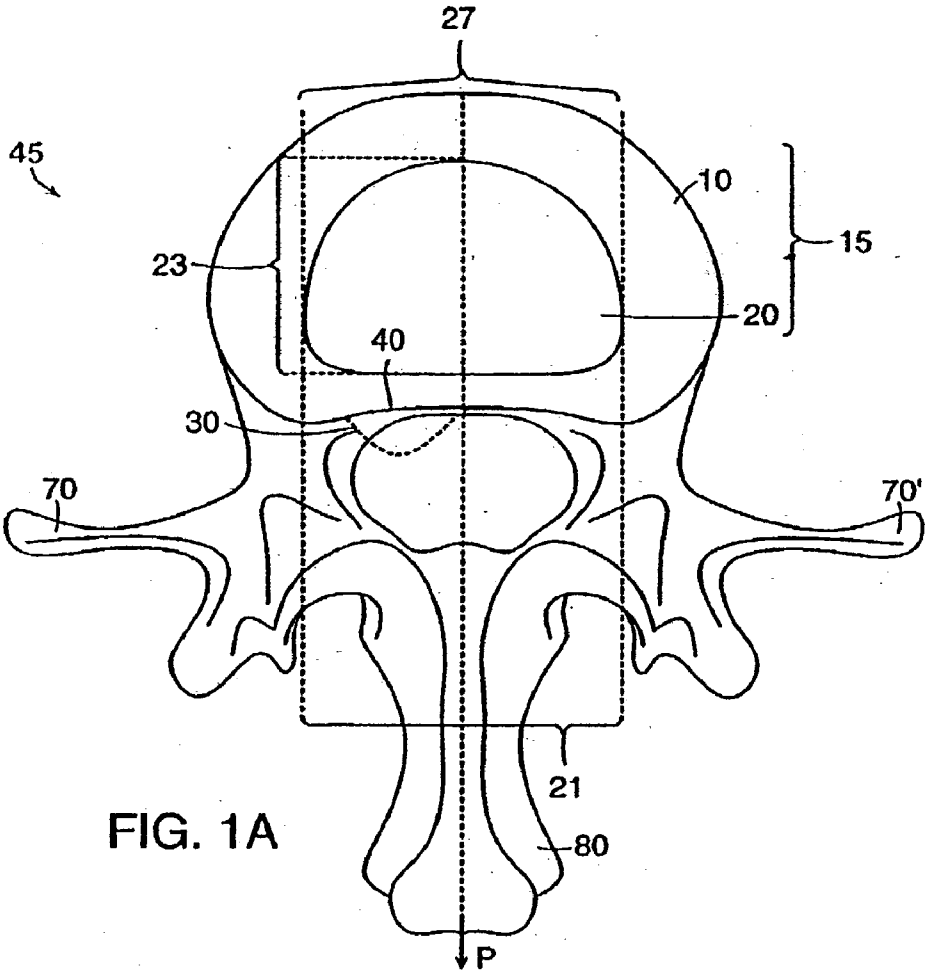

27
45
10
15
23
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40
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70
70'
21
80
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FIG. 1A

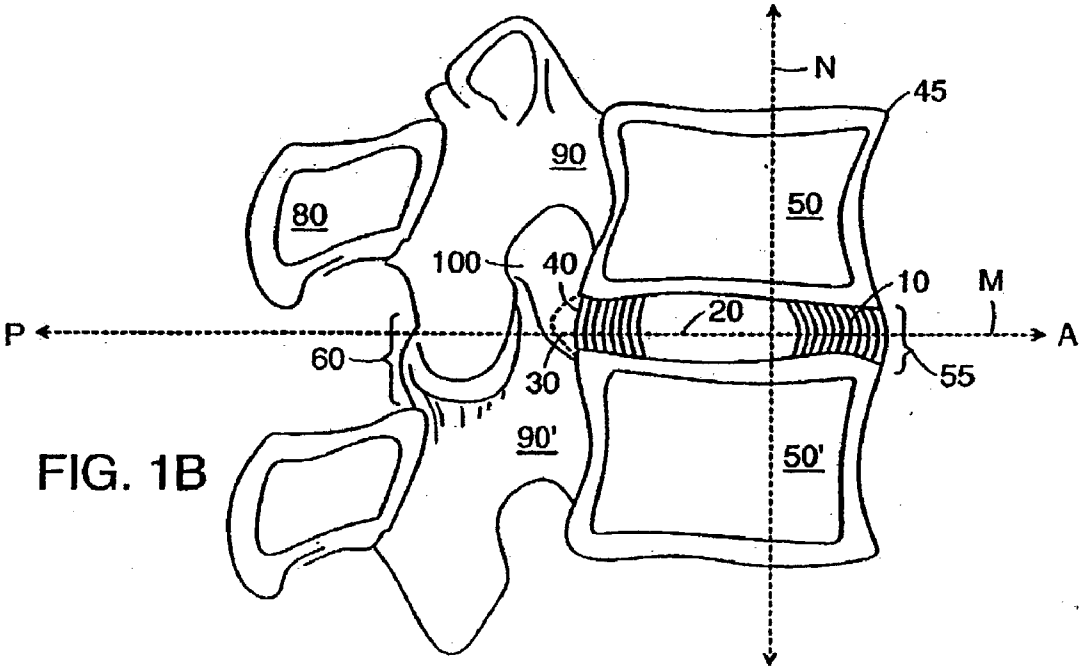

N
45
90
80
50
100
40
10
M
20
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A
60
30
55
90'
50'

FIG. 1B

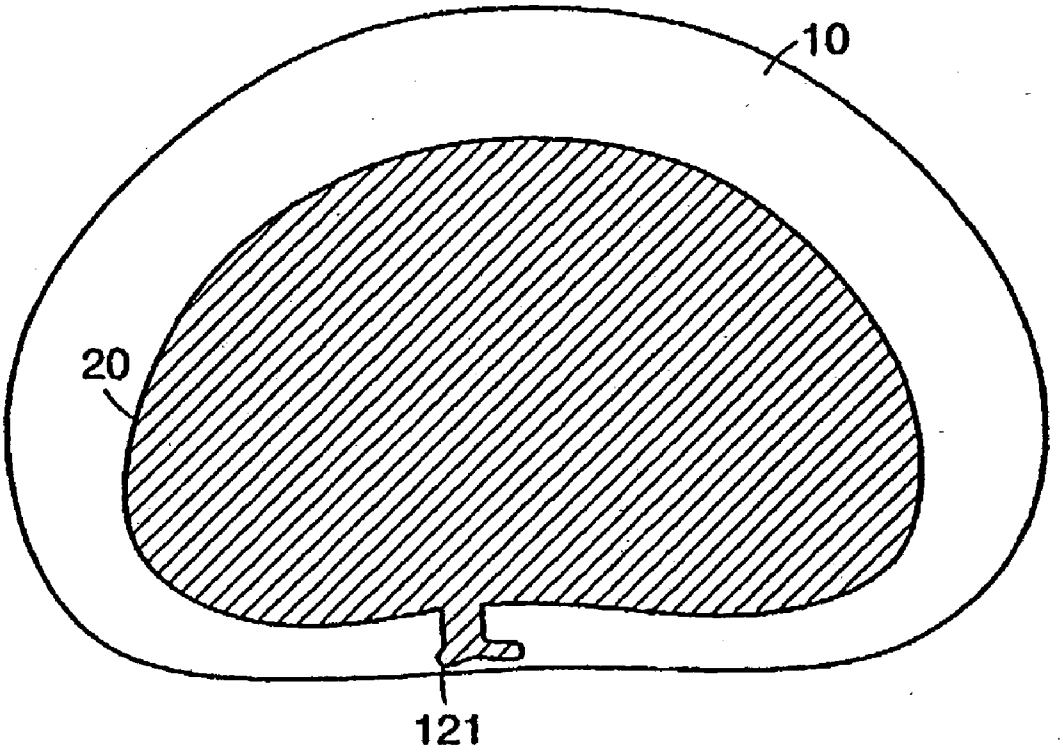


FIG. 1C

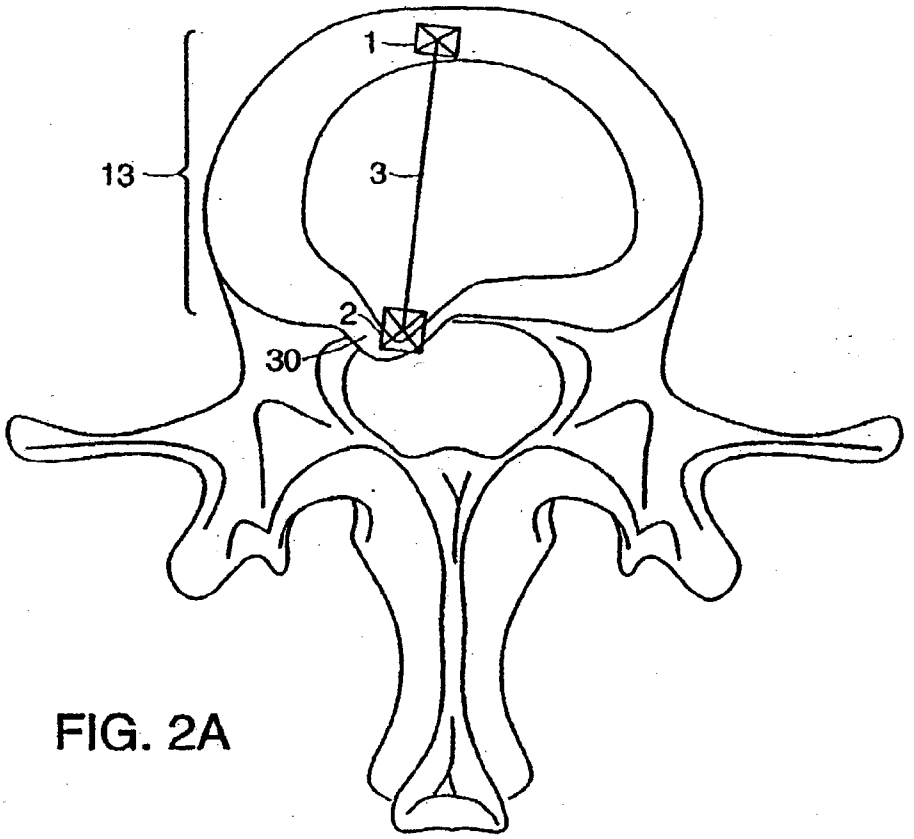


FIG. 2A

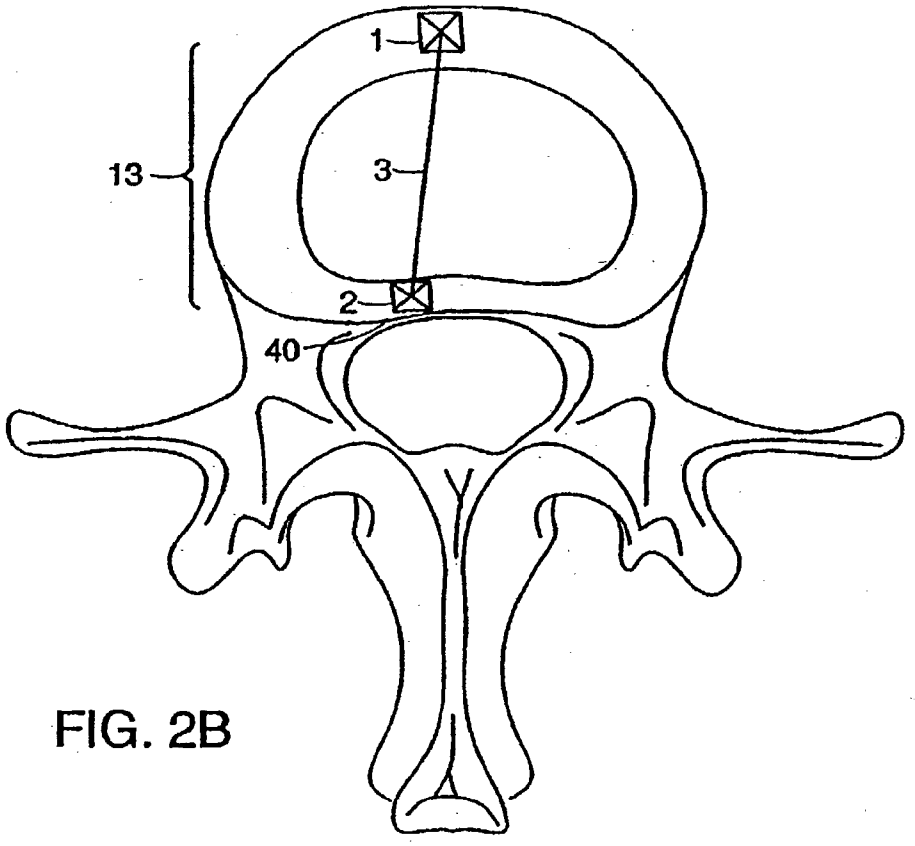


FIG. 2B

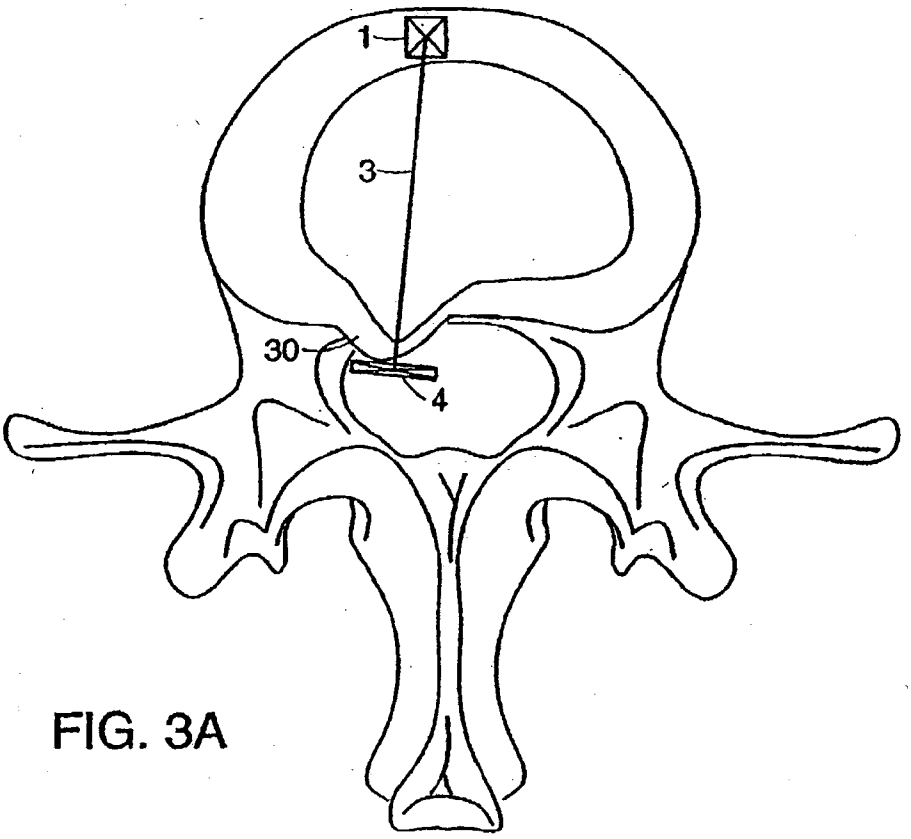


FIG. 3A

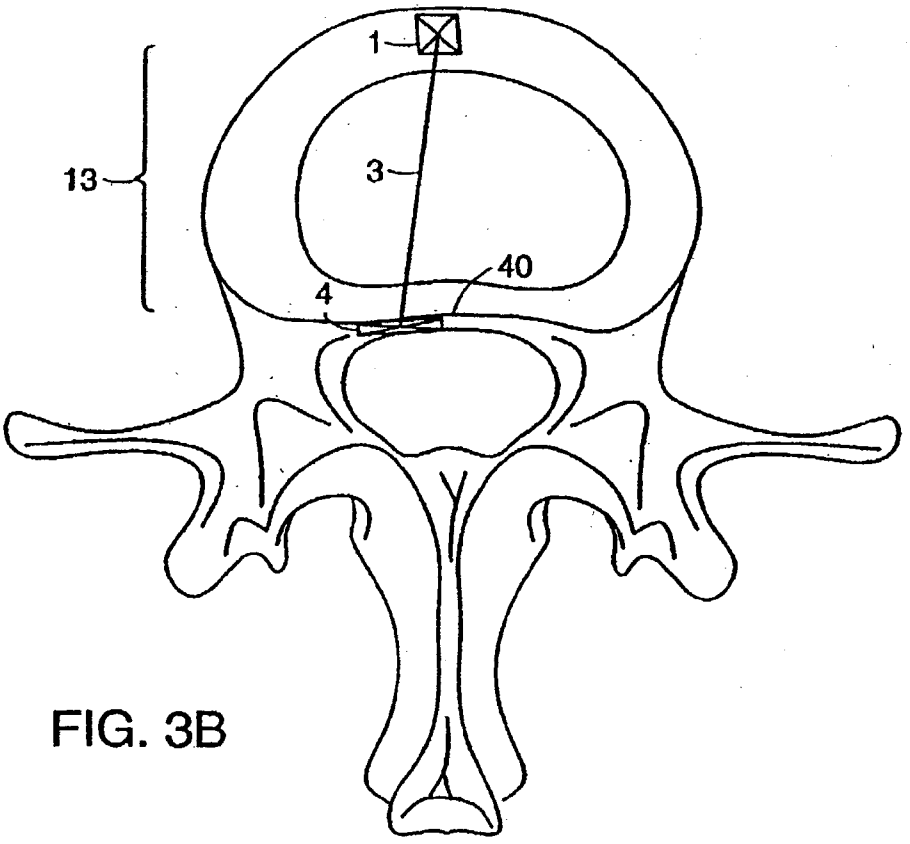


FIG. 3B

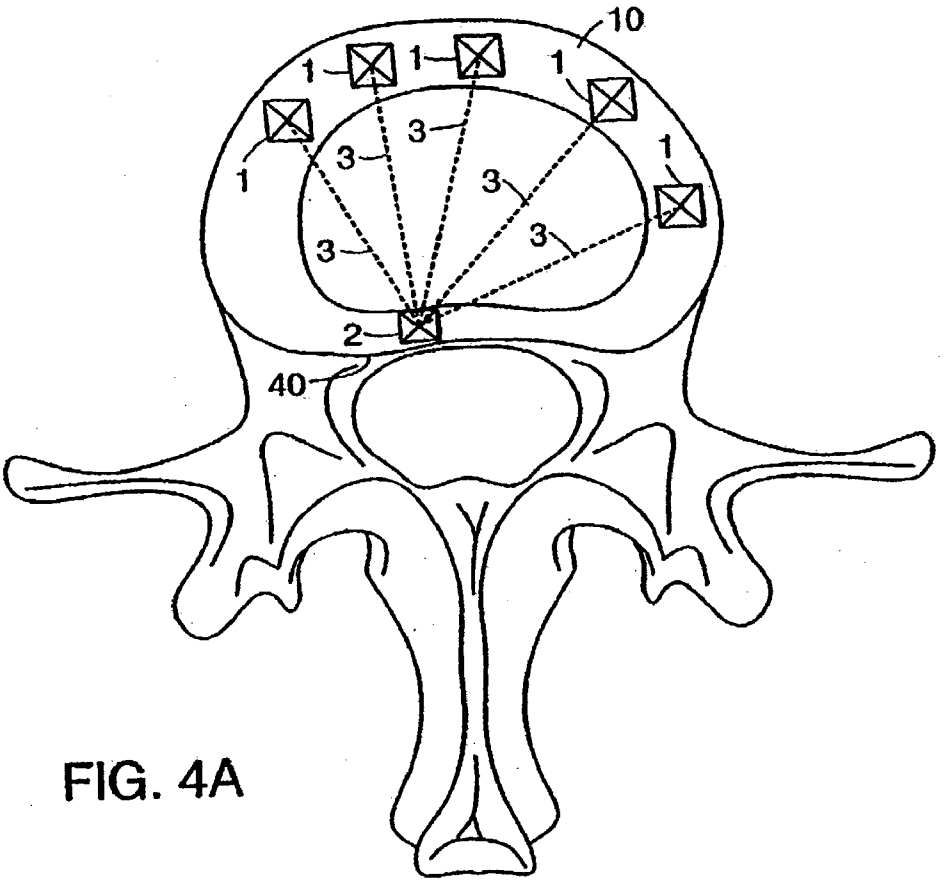


FIG. 4A

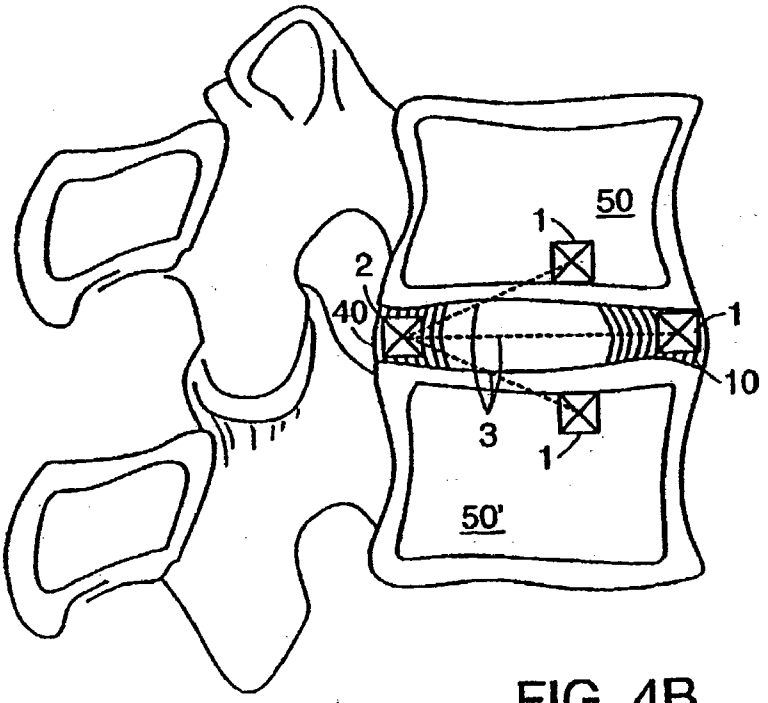


FIG. 4B

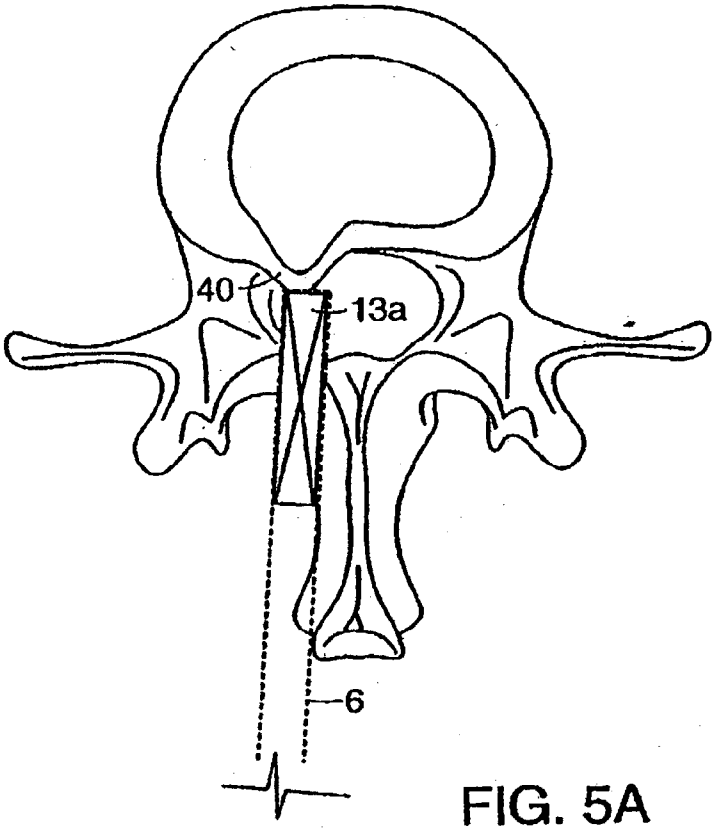


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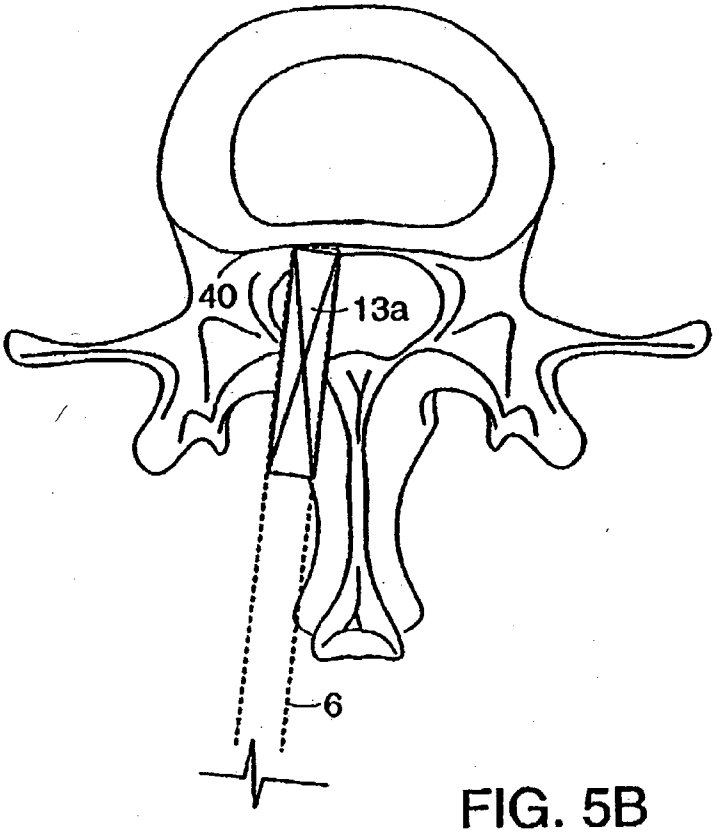


FIG. 5B

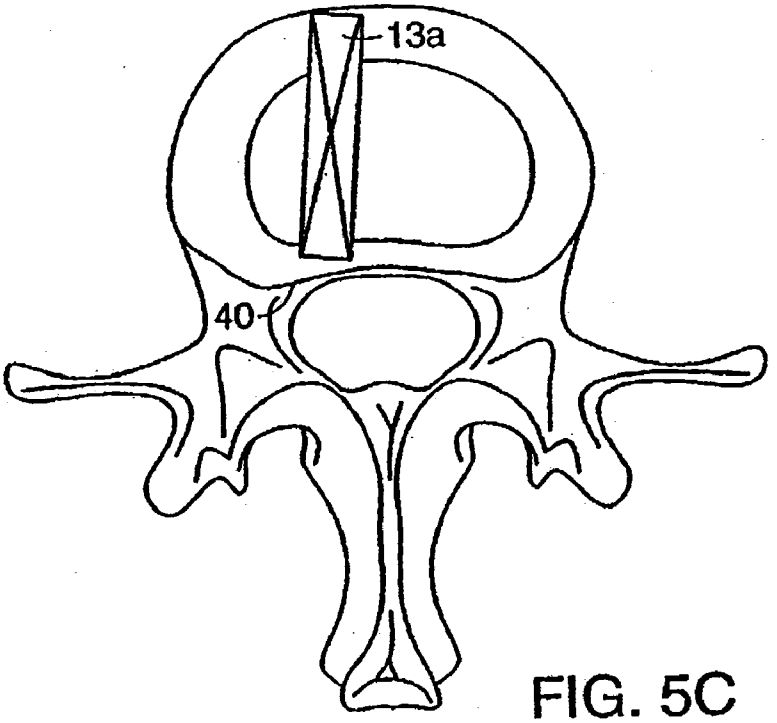


FIG. 5C

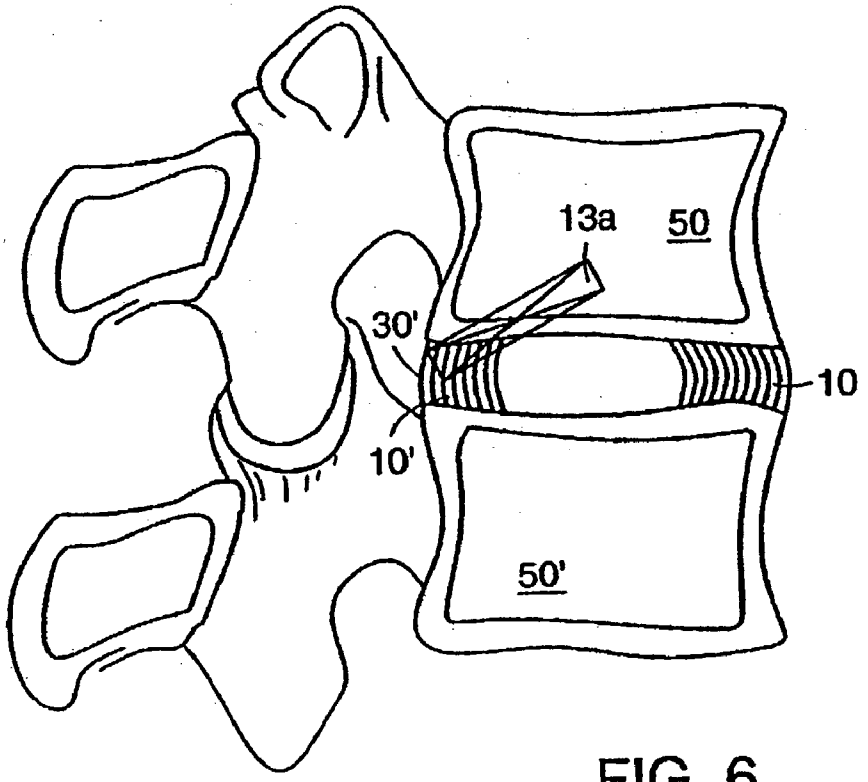


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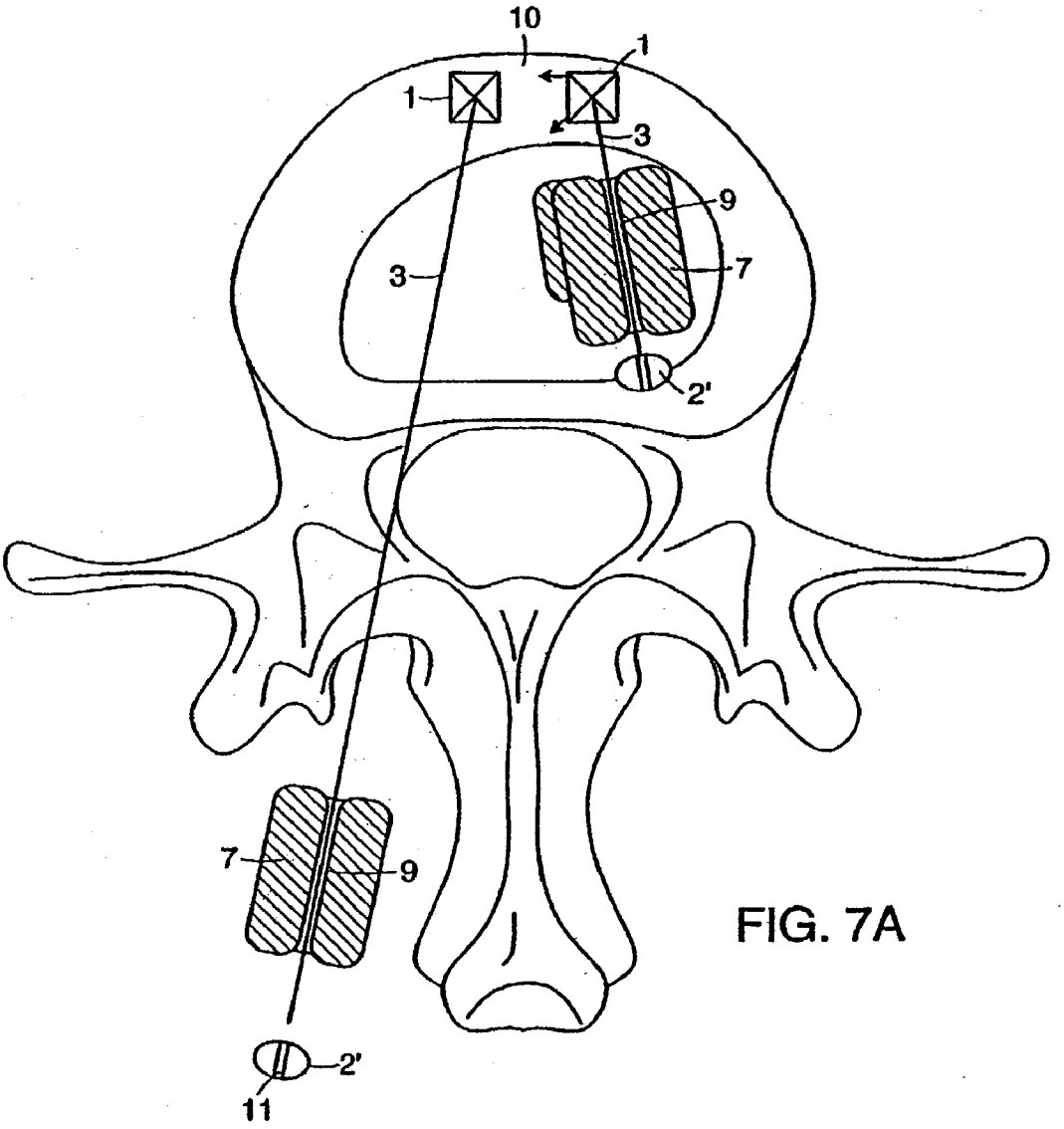


FIG. 7A

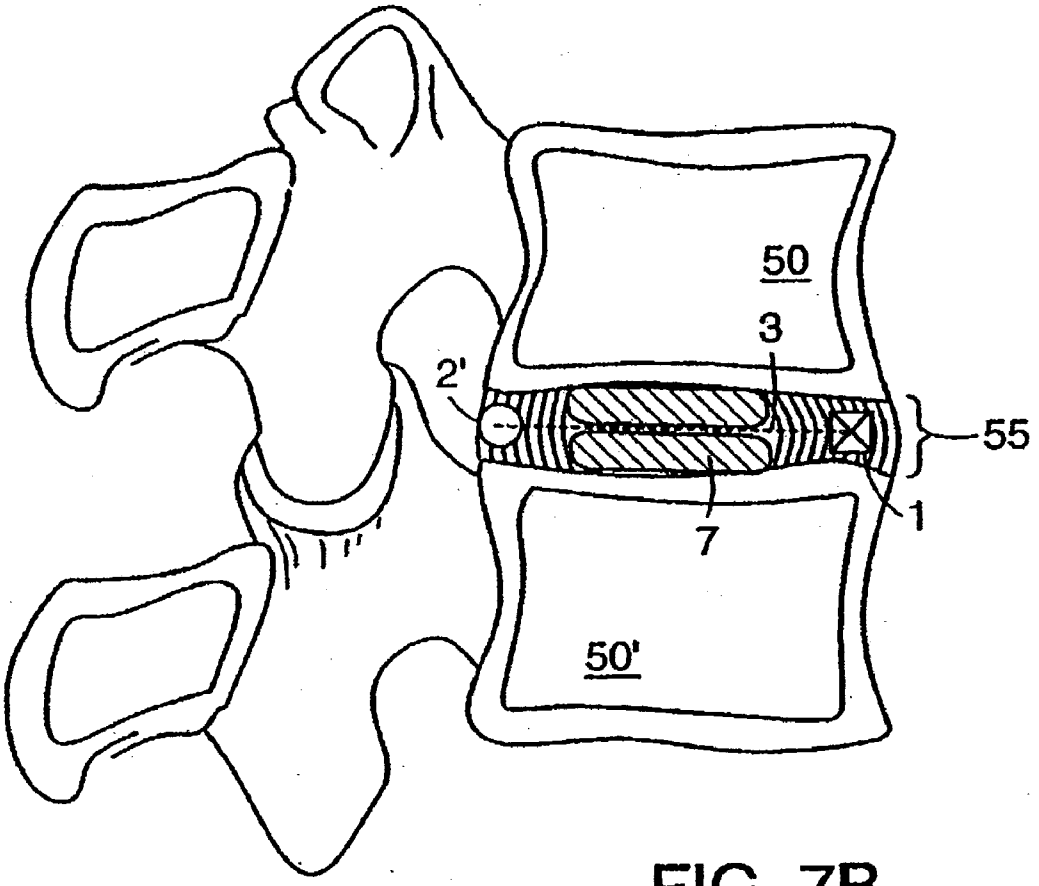


FIG. 7B

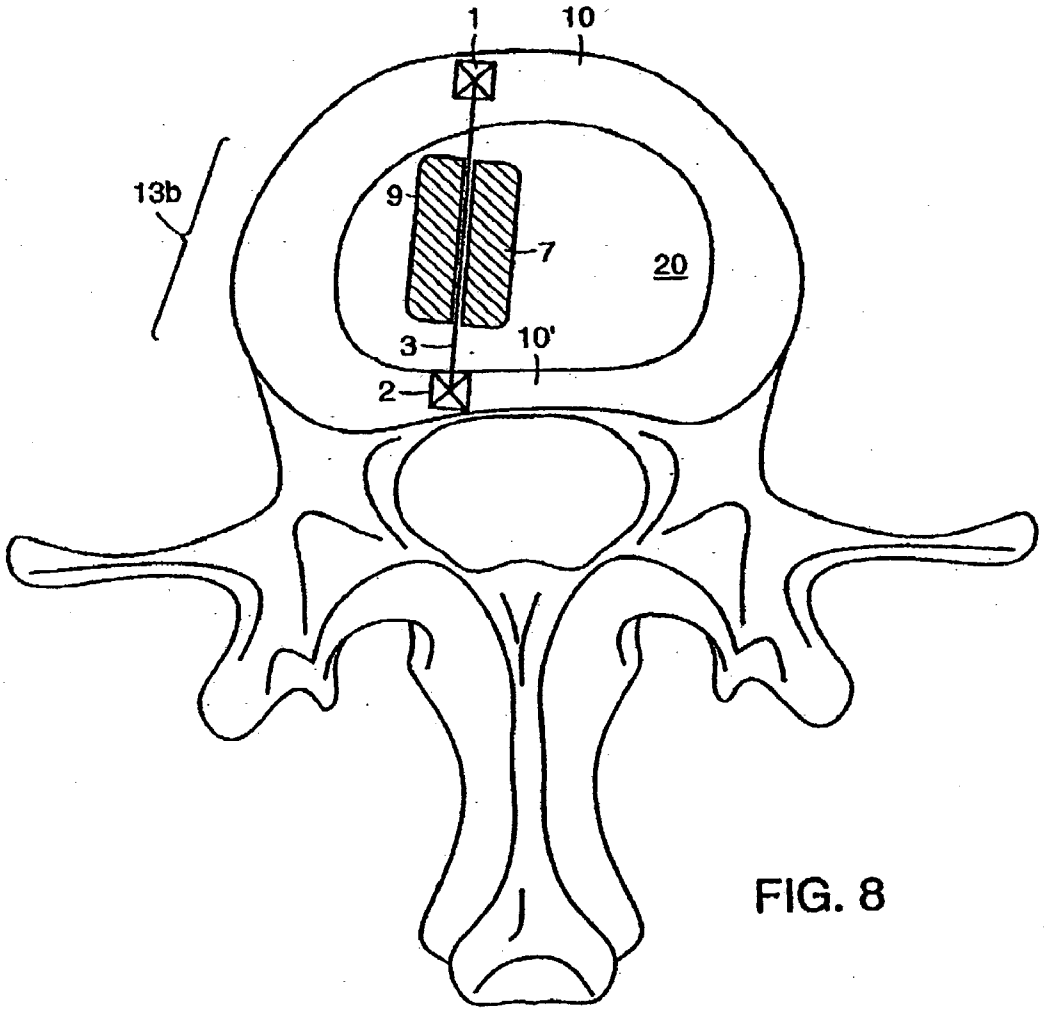


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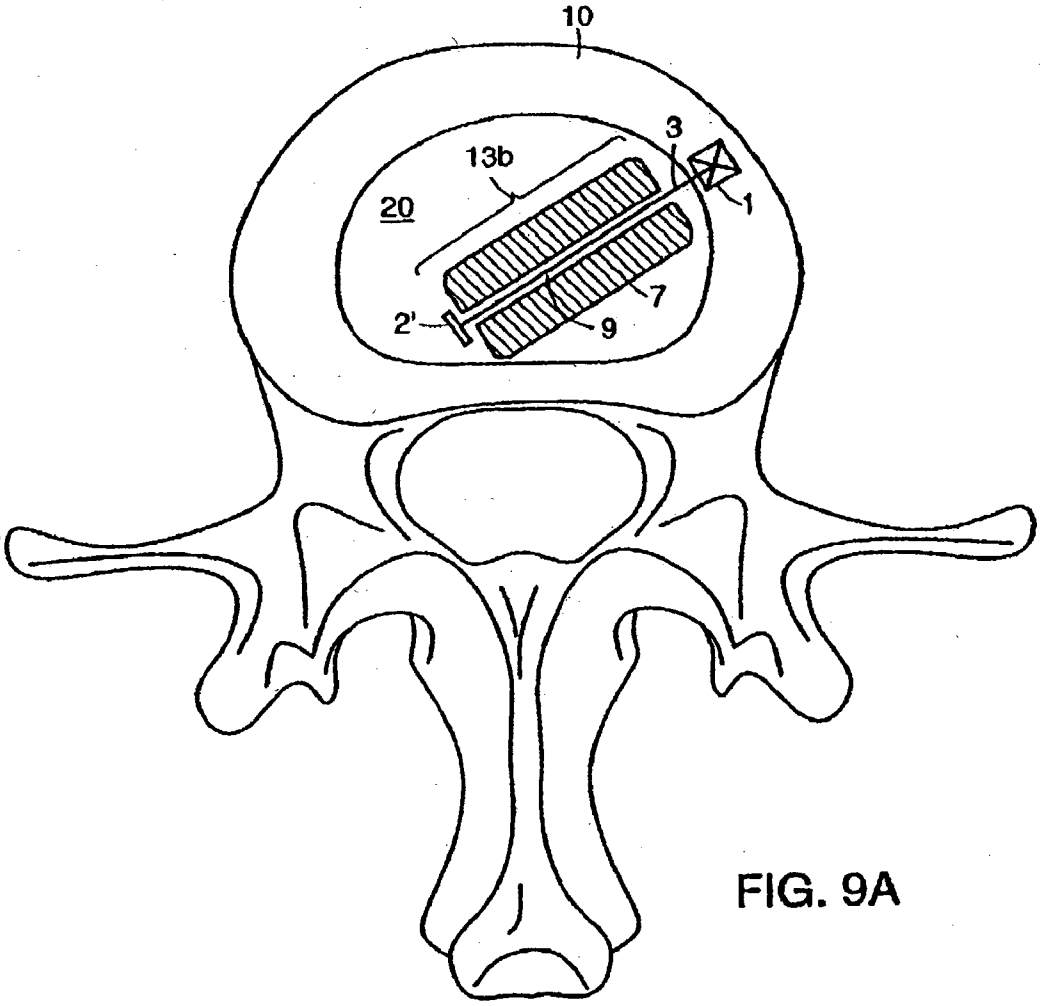


FIG. 9A

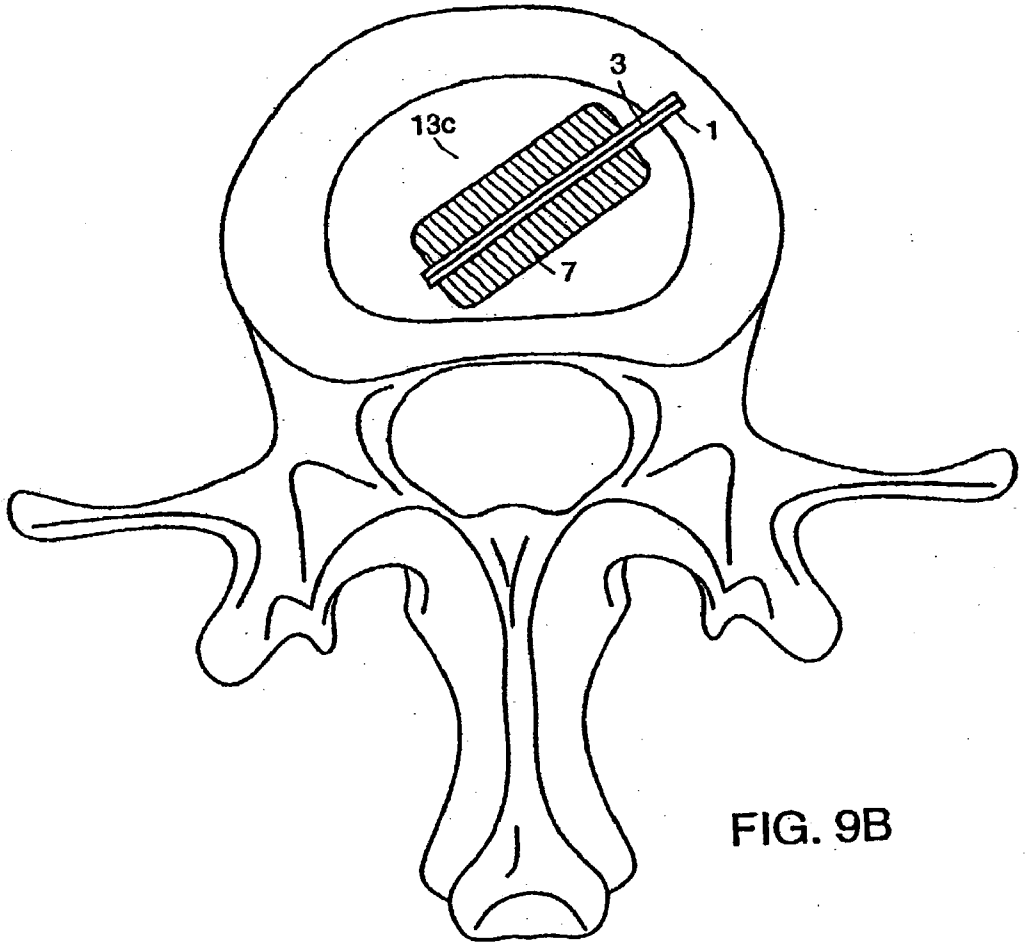


FIG. 9B

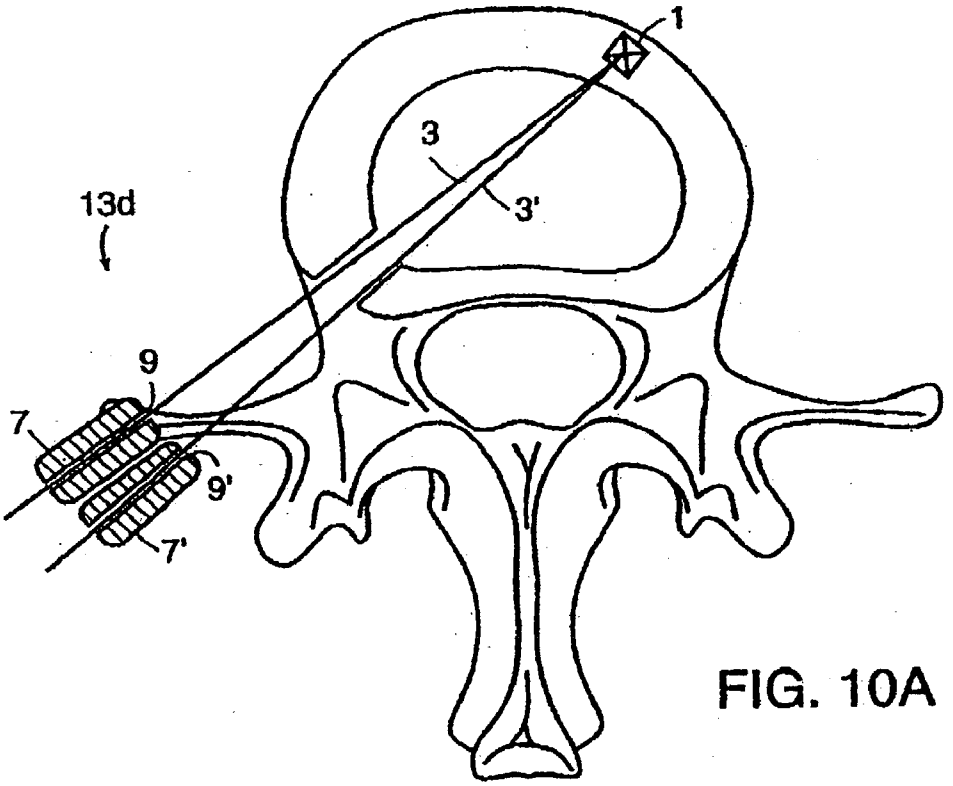


FIG. 10A

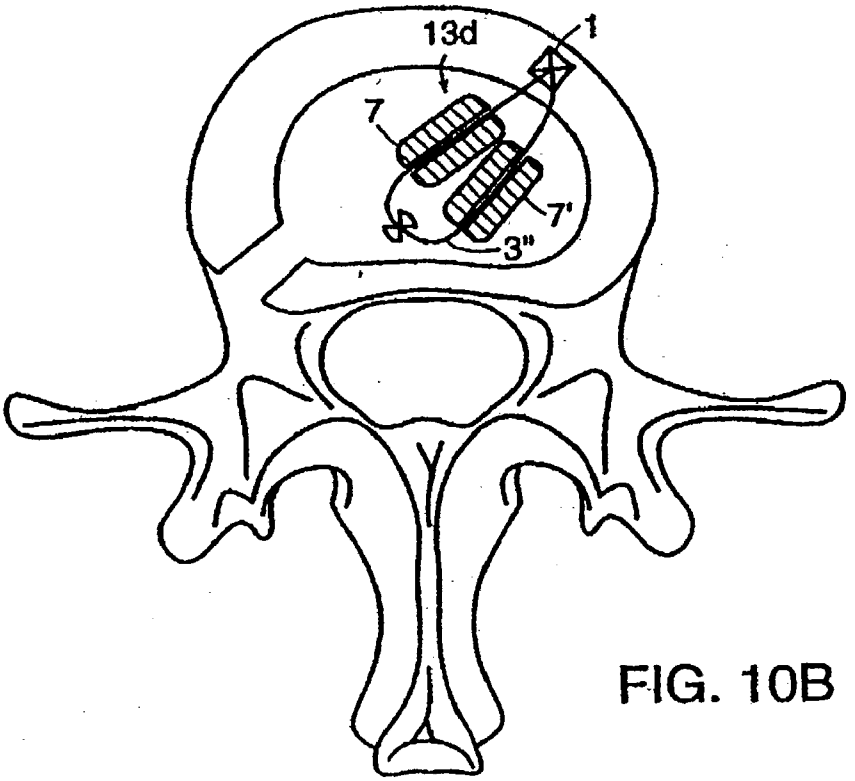


FIG. 10B

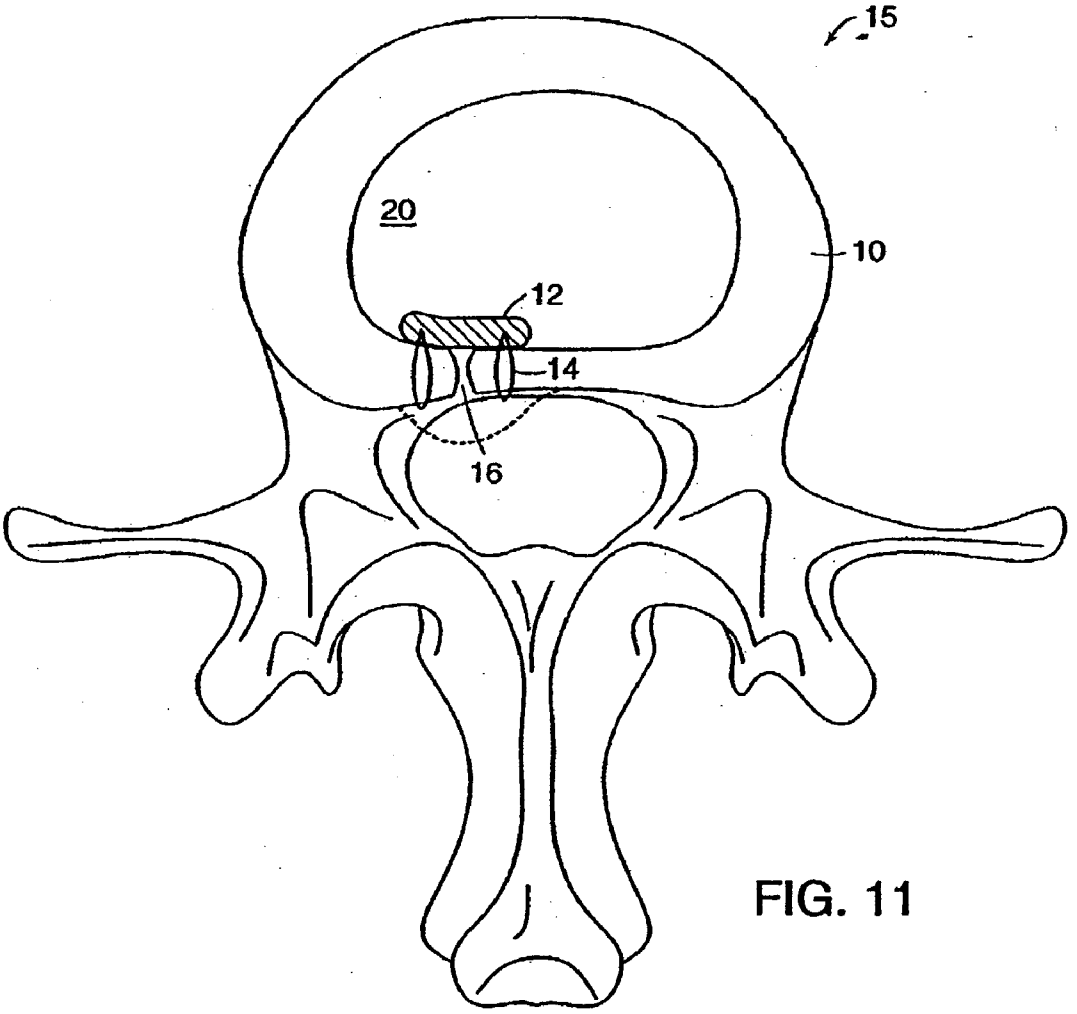


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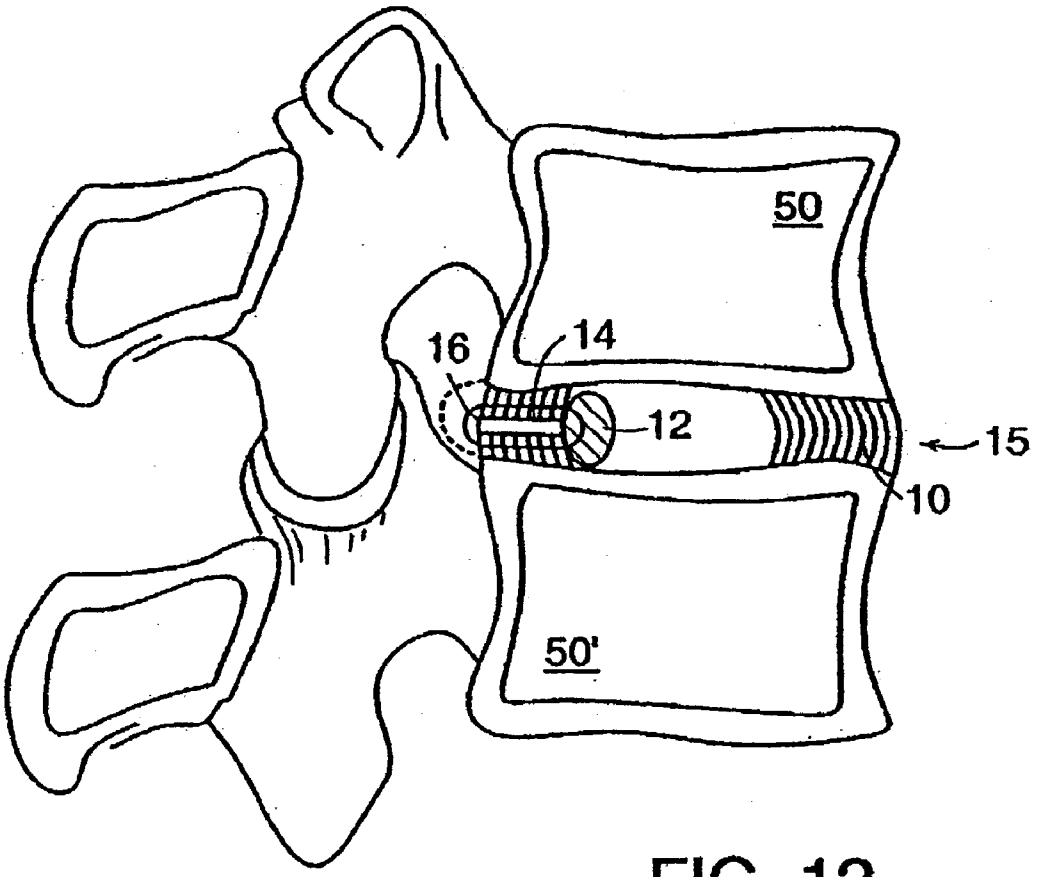


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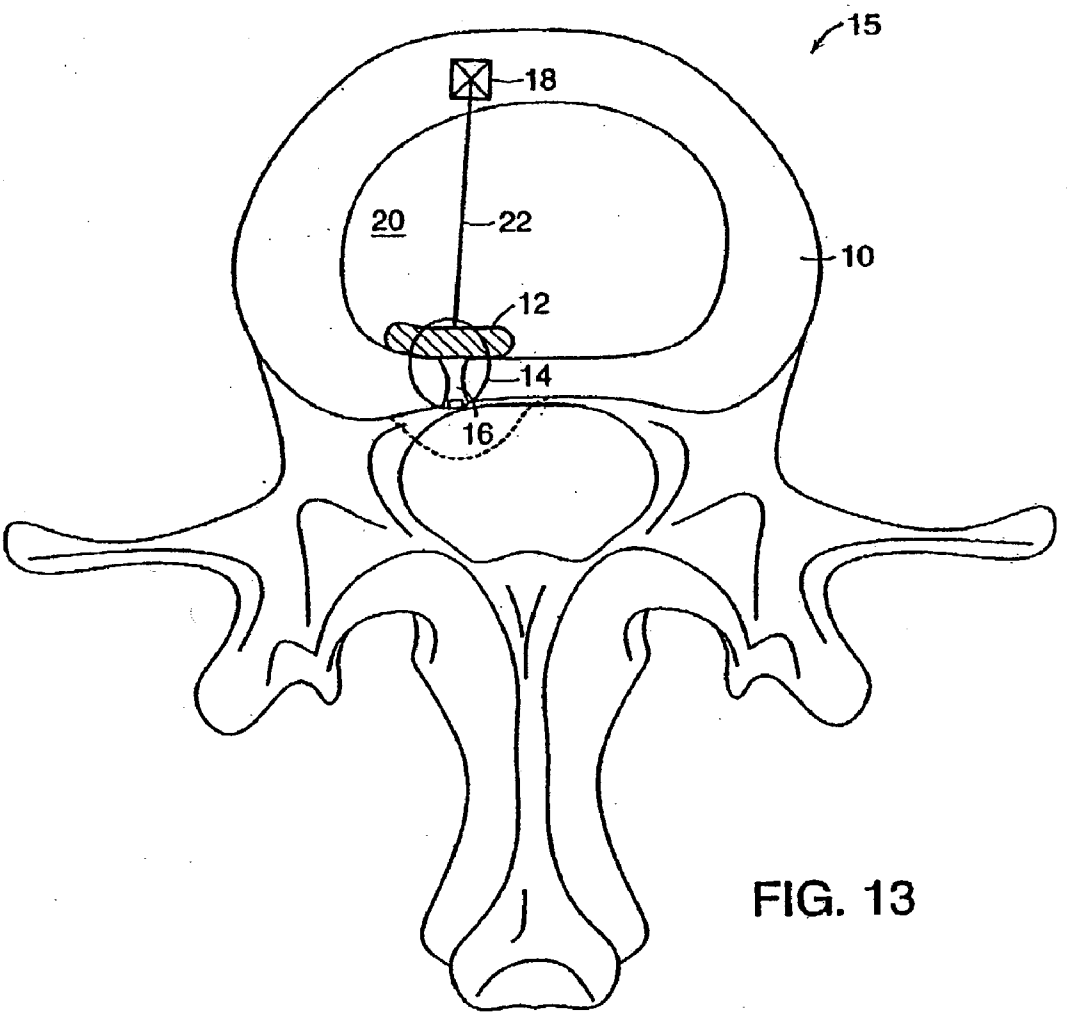


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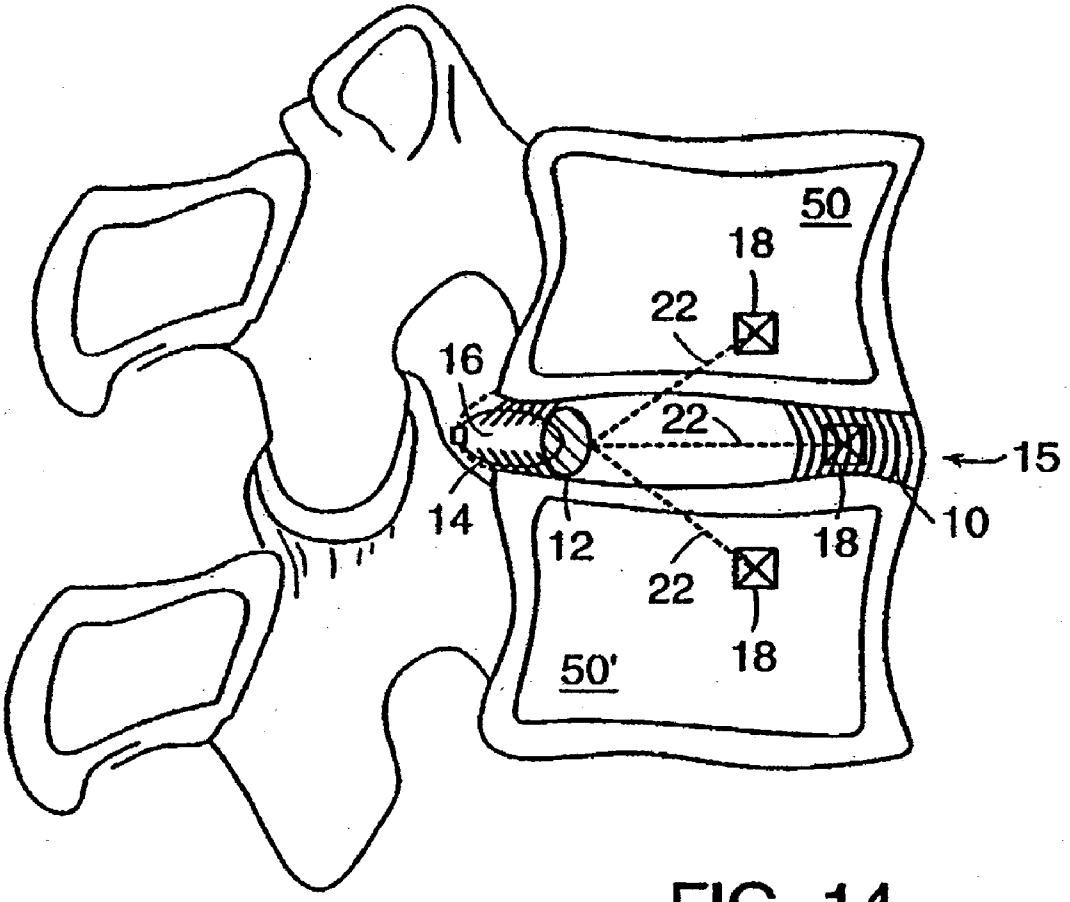


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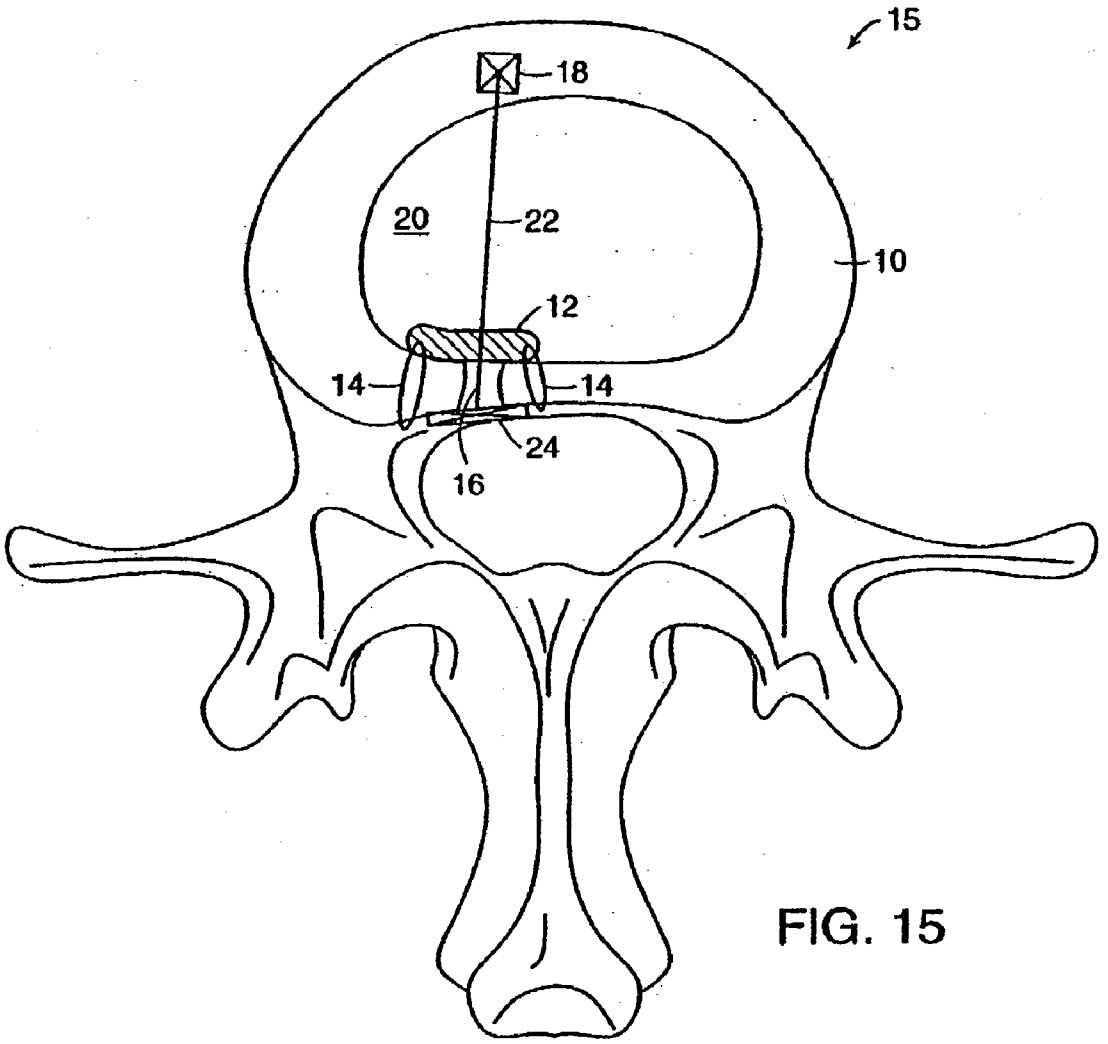


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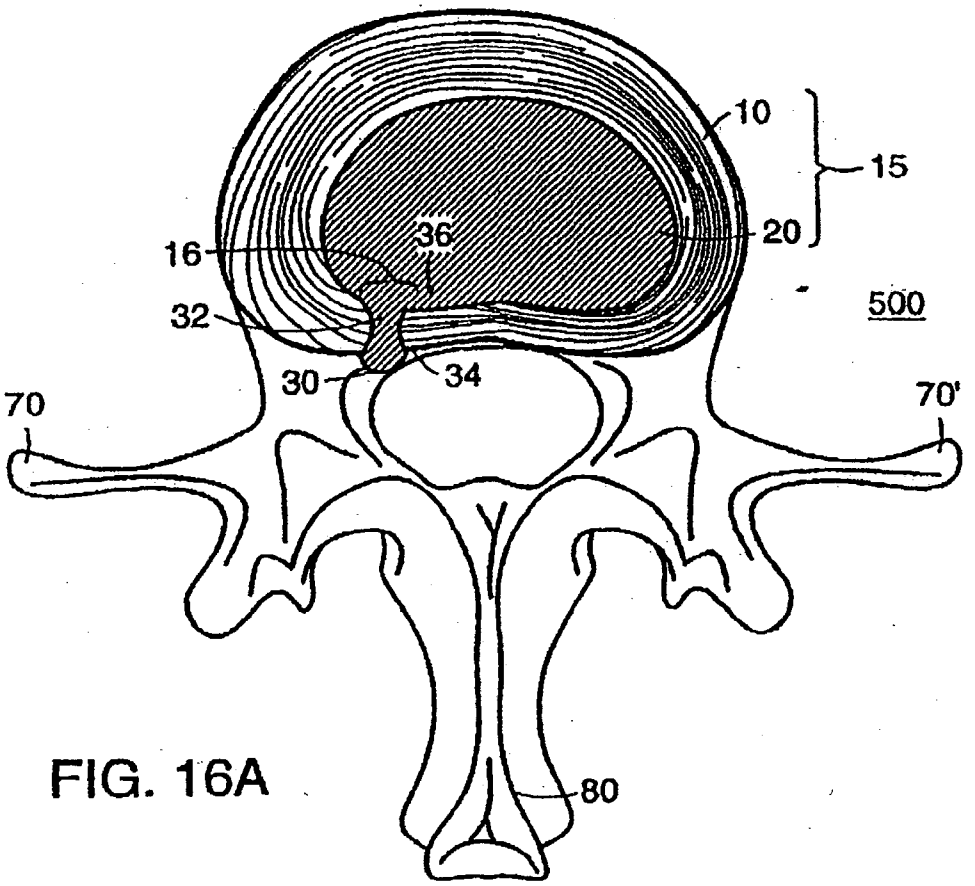


FIG. 16A

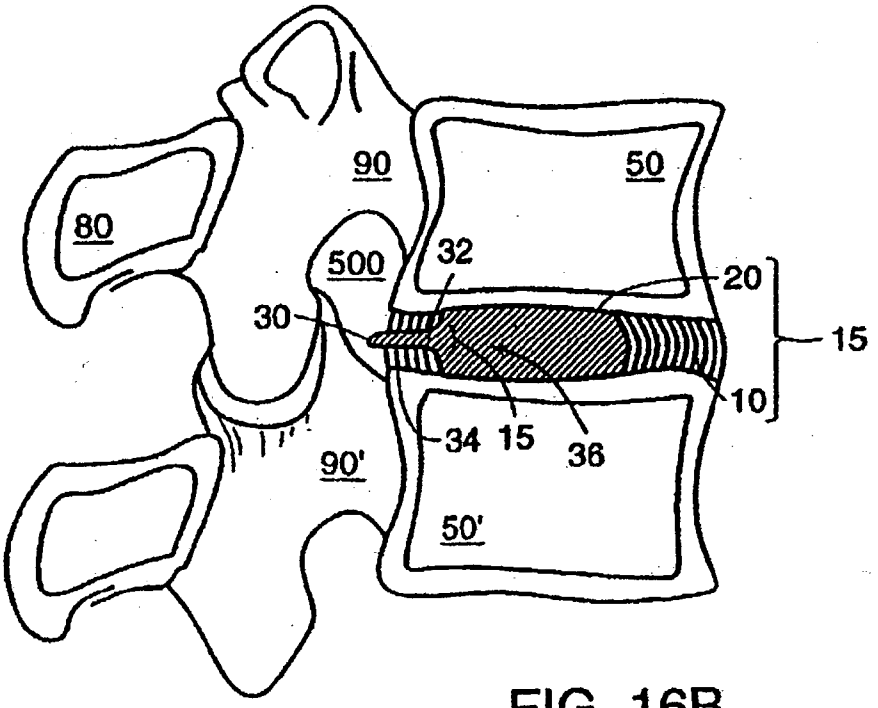


FIG. 16B

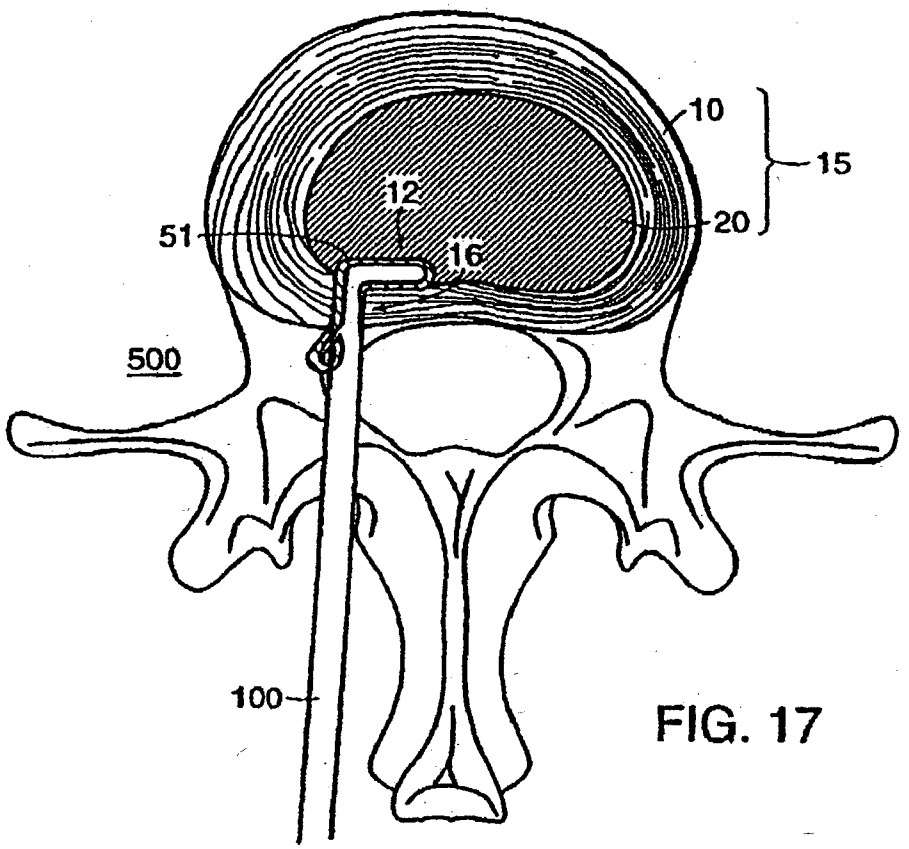


FIG. 17

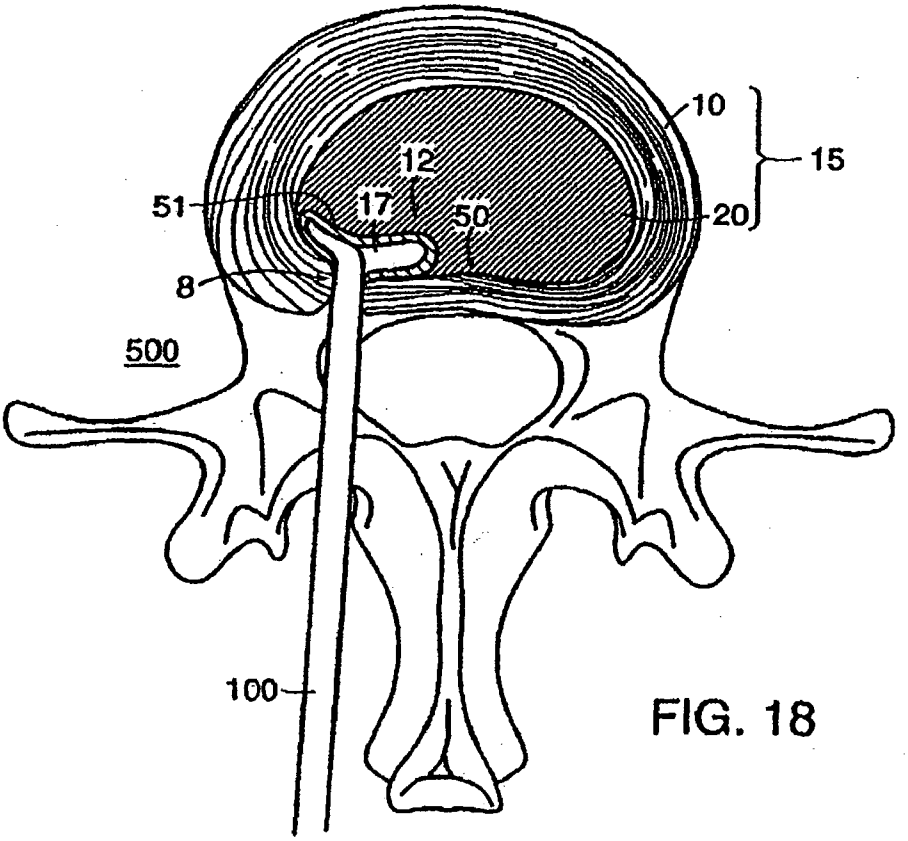


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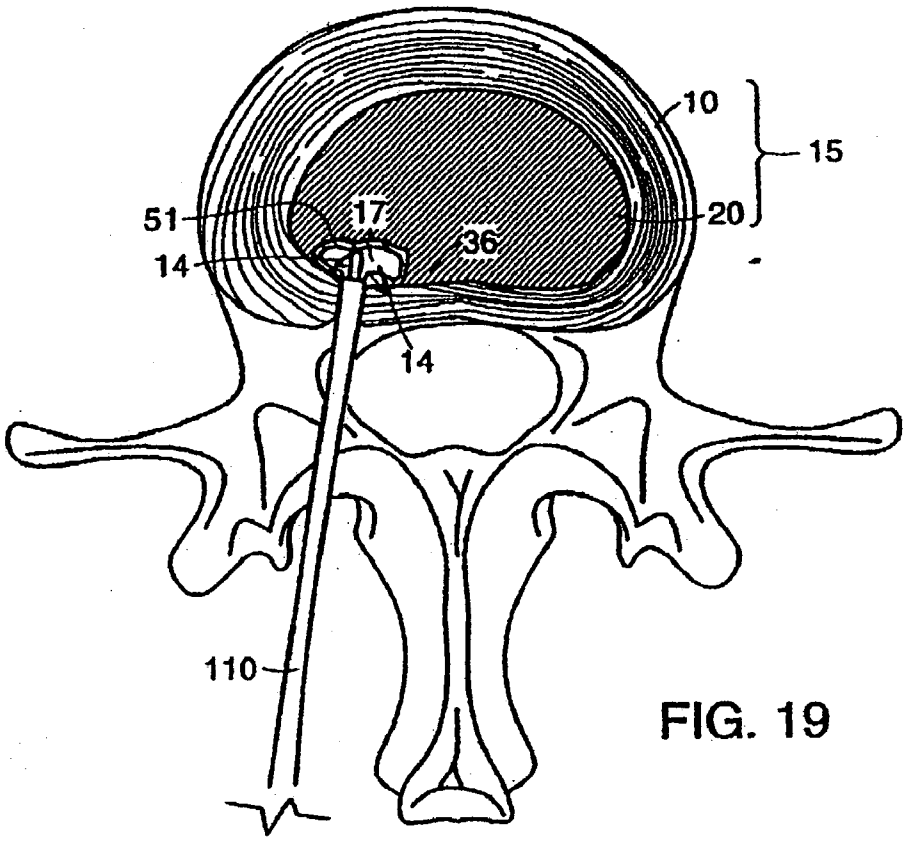


FIG. 19

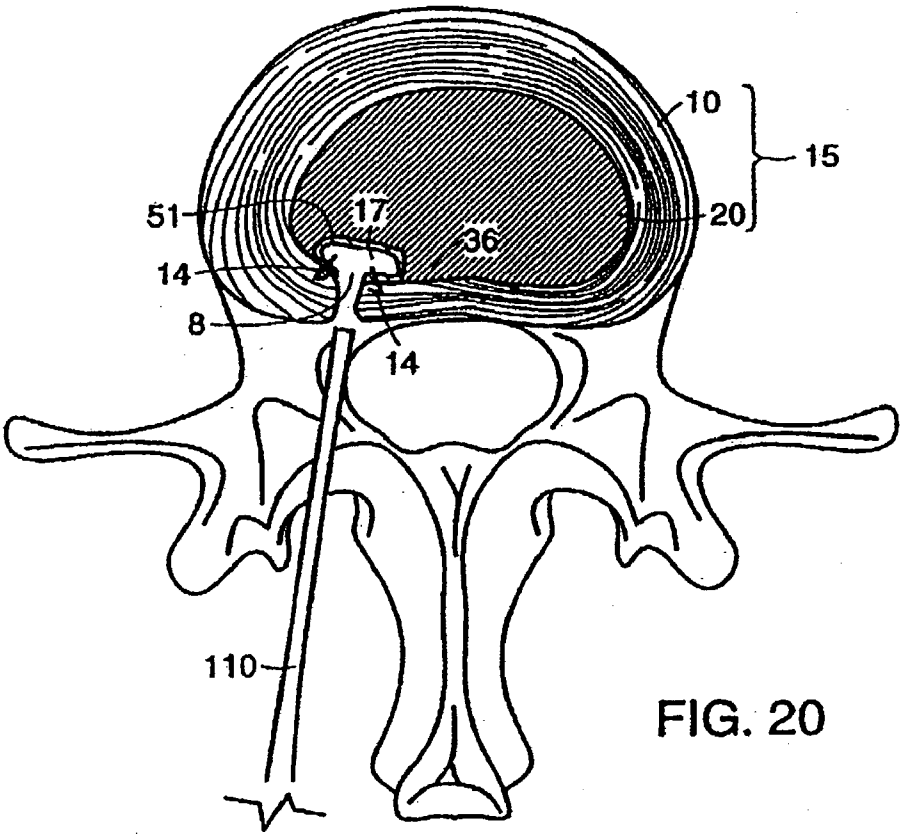


FIG. 20

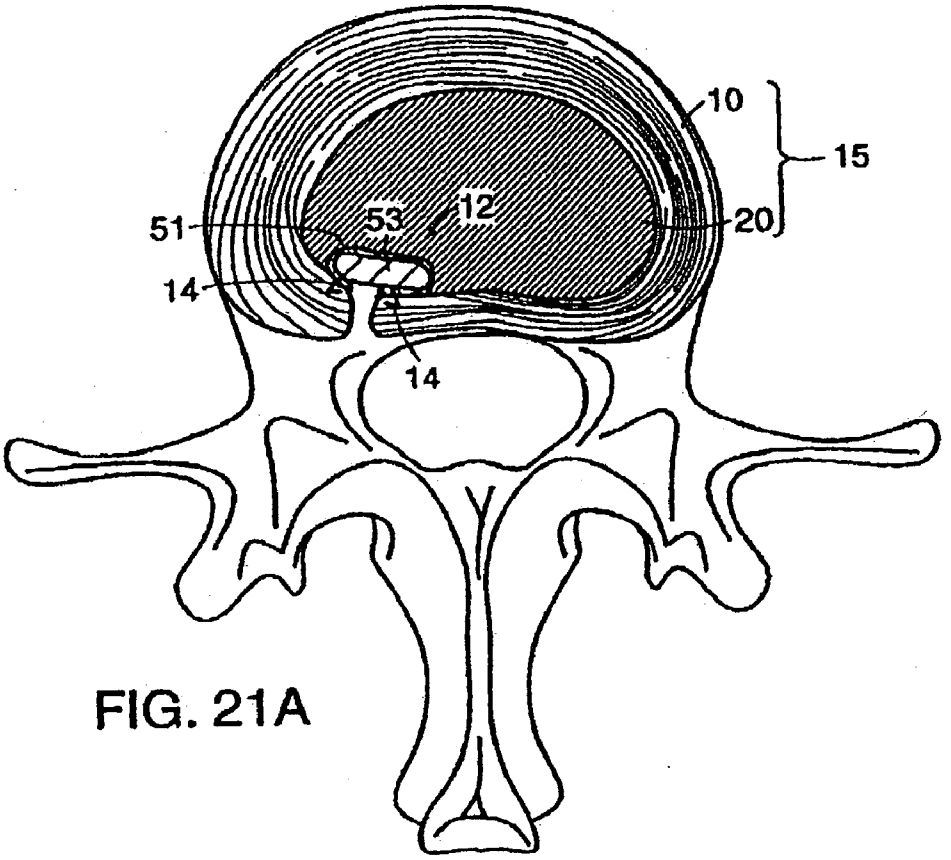


FIG. 21A

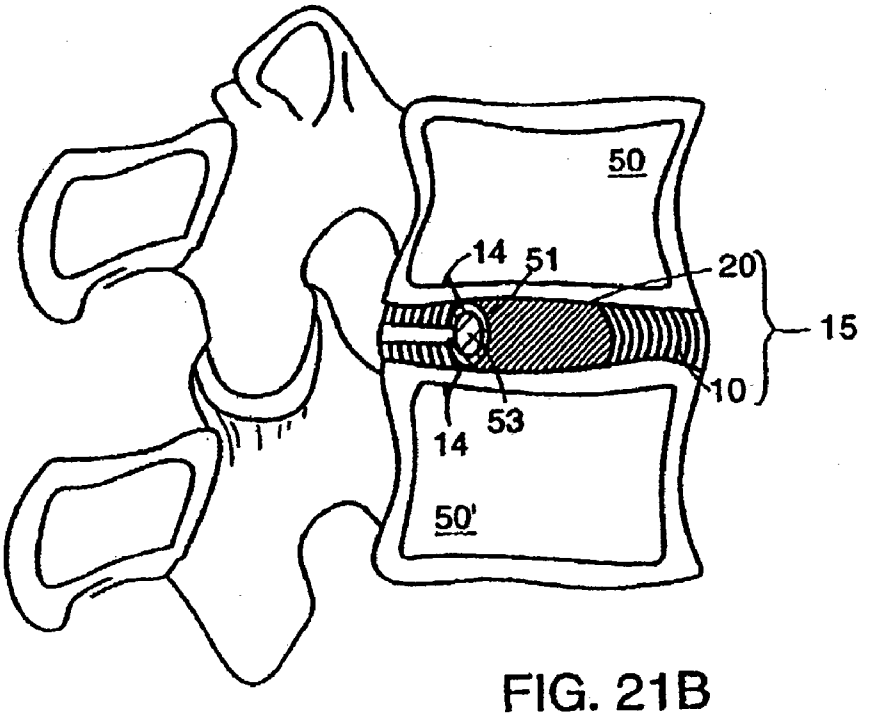


FIG. 21B

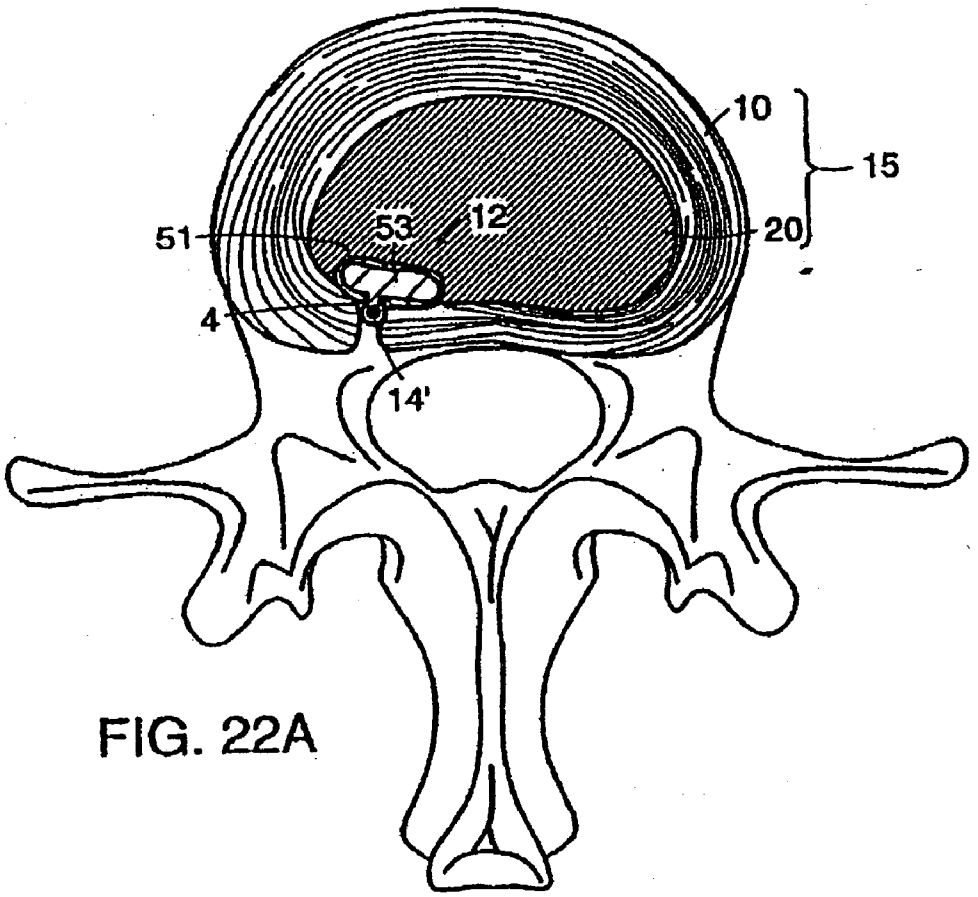


FIG. 22A

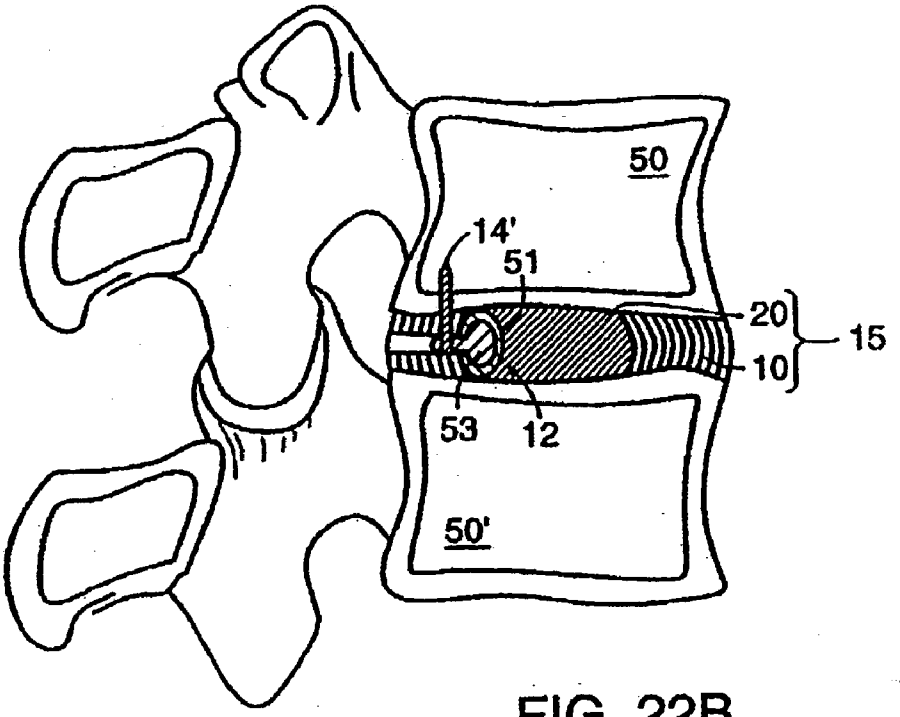


FIG. 22B

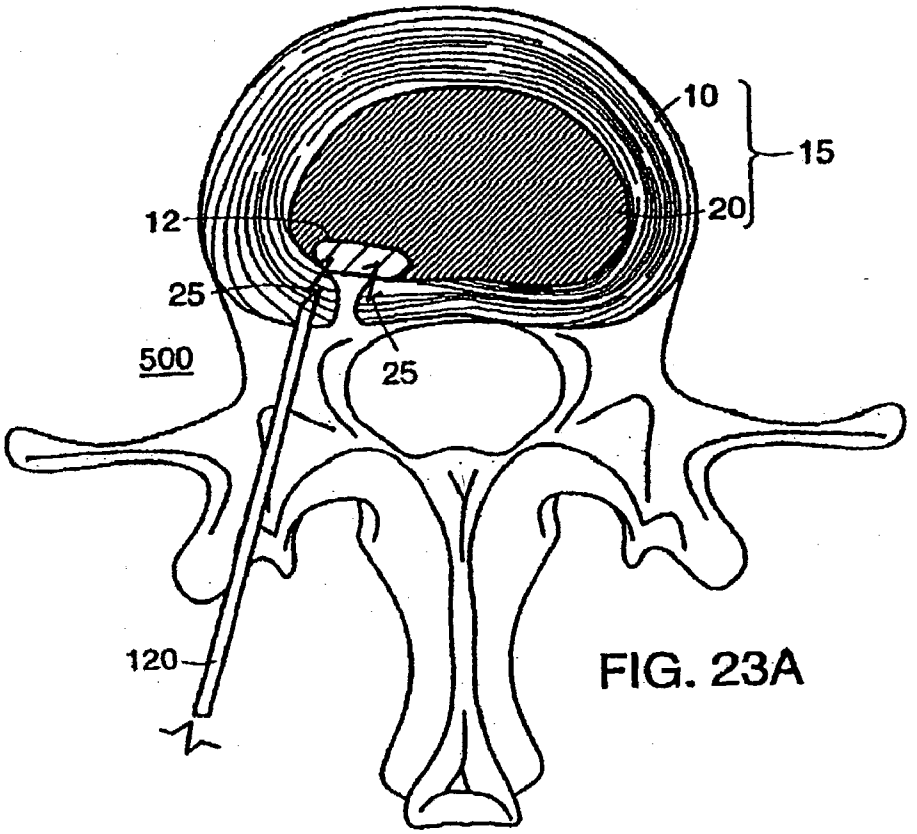


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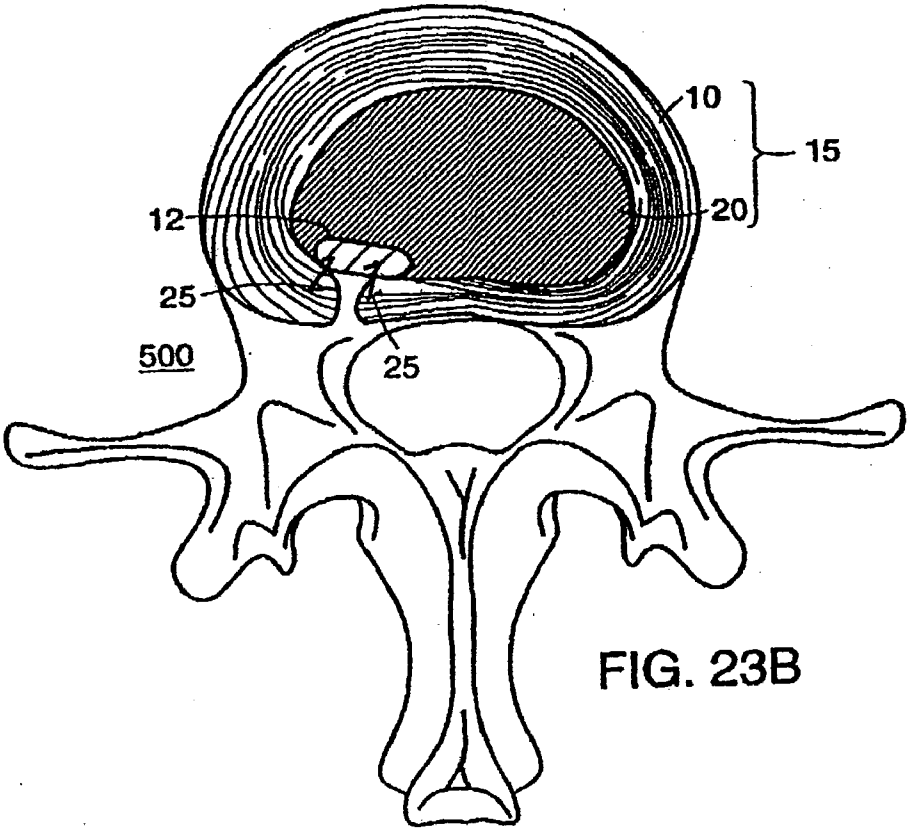


FIG. 23B

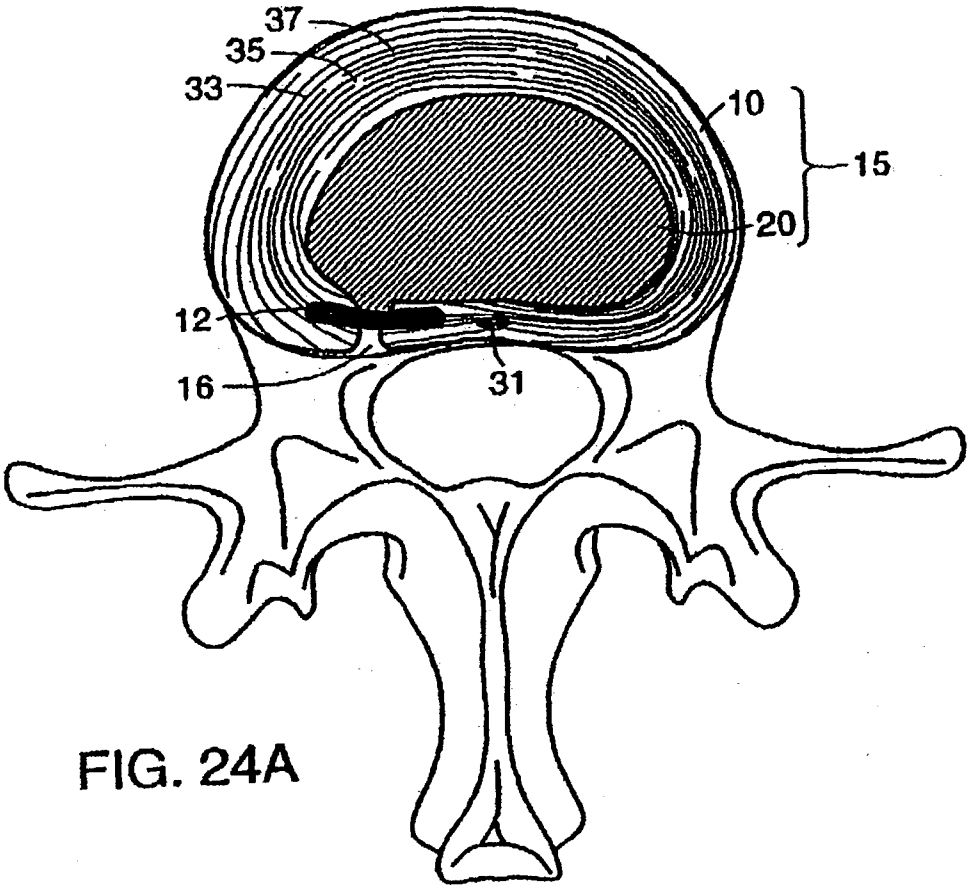


FIG. 24A

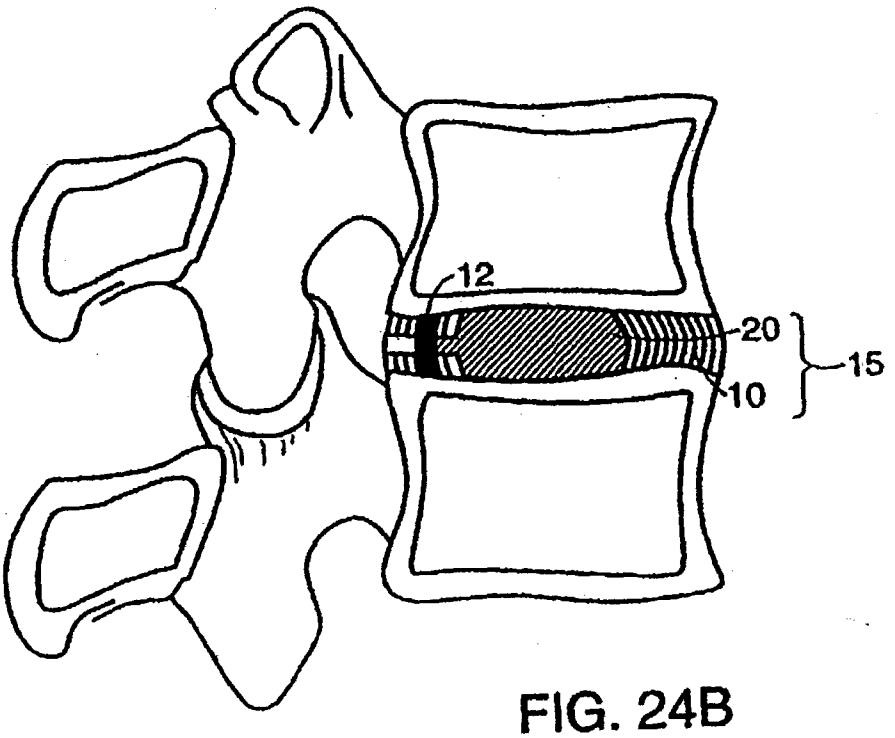


FIG. 24B

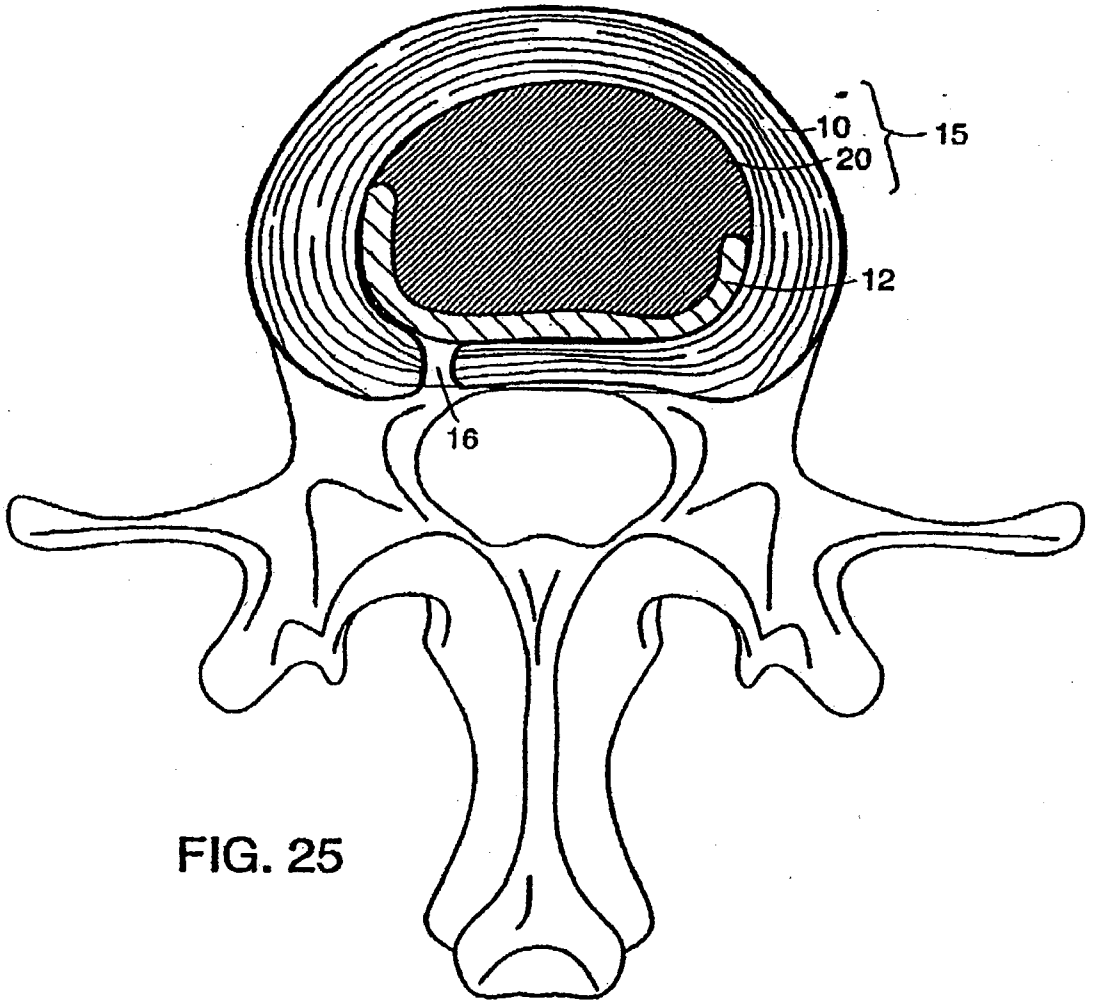


FIG. 25

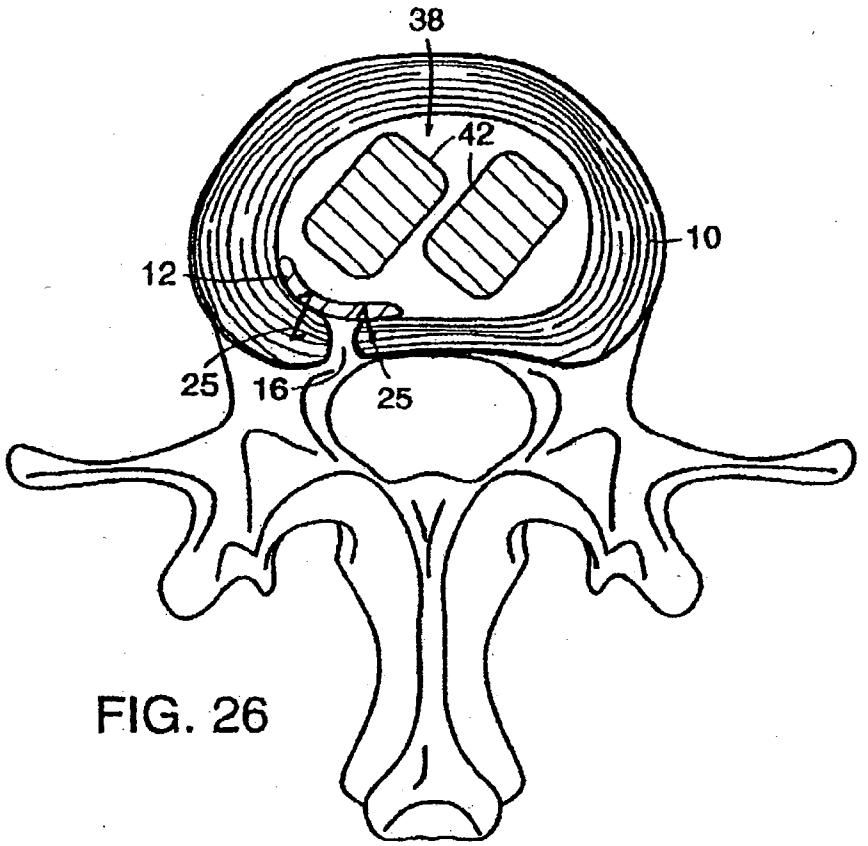


FIG. 26

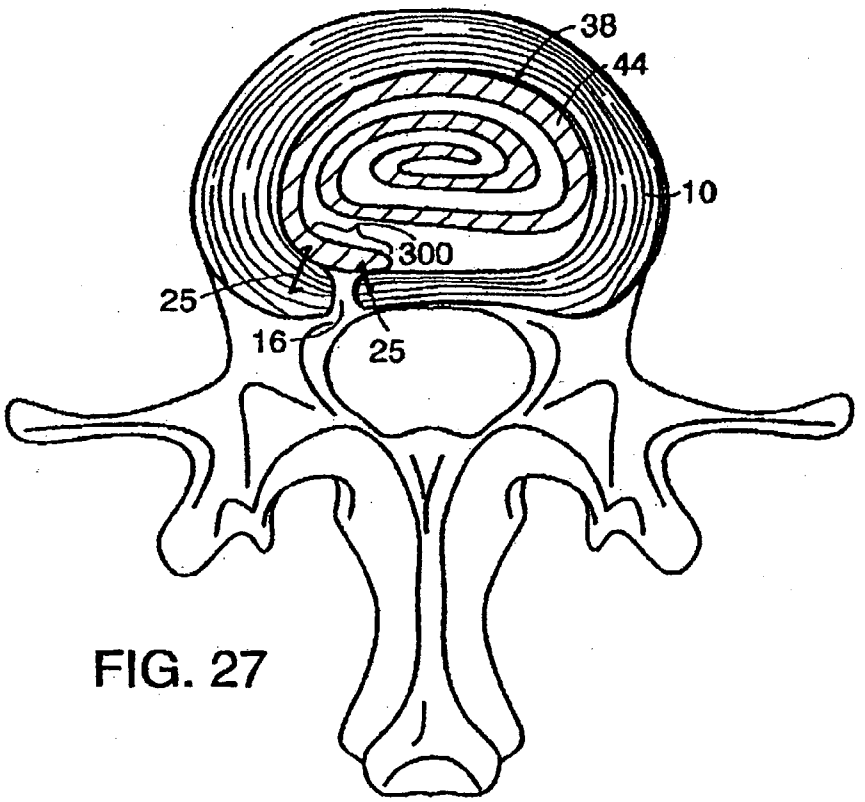


FIG. 27

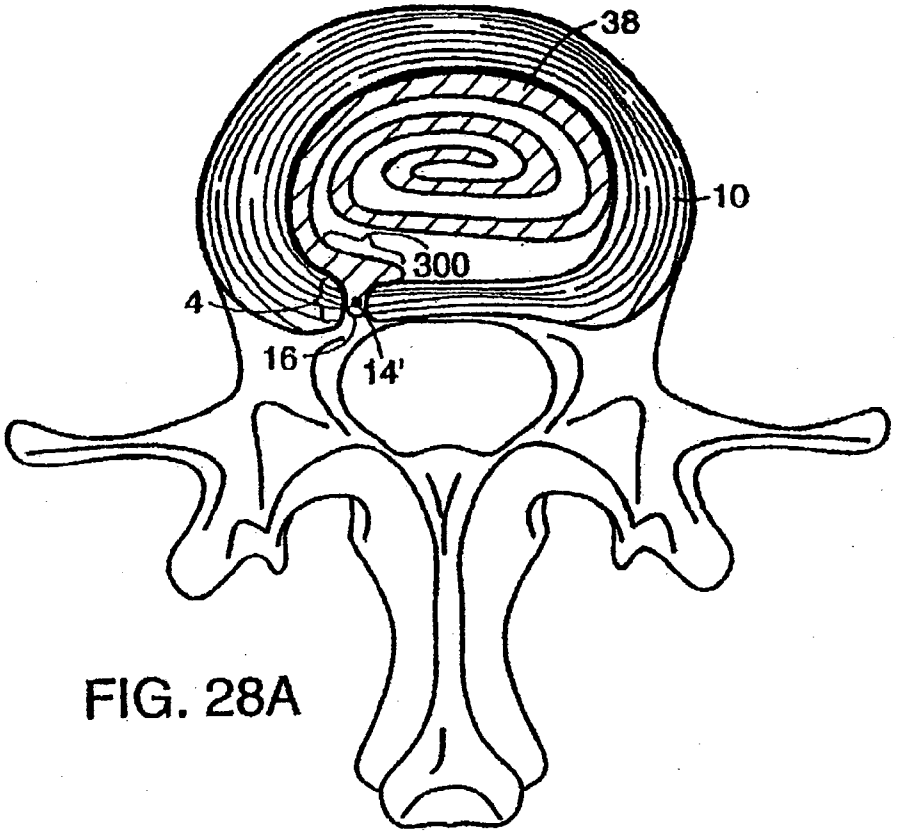


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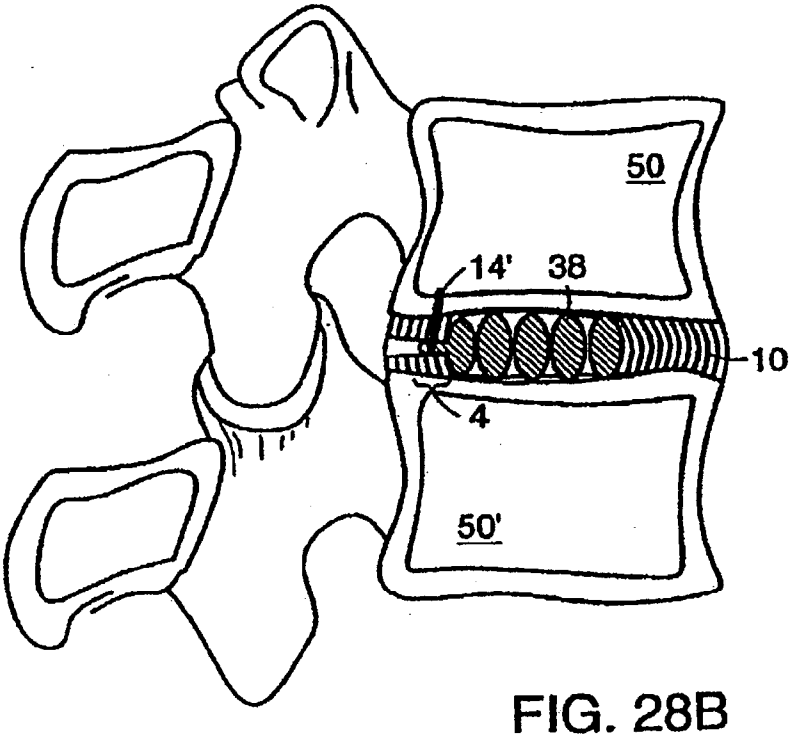


FIG. 28B

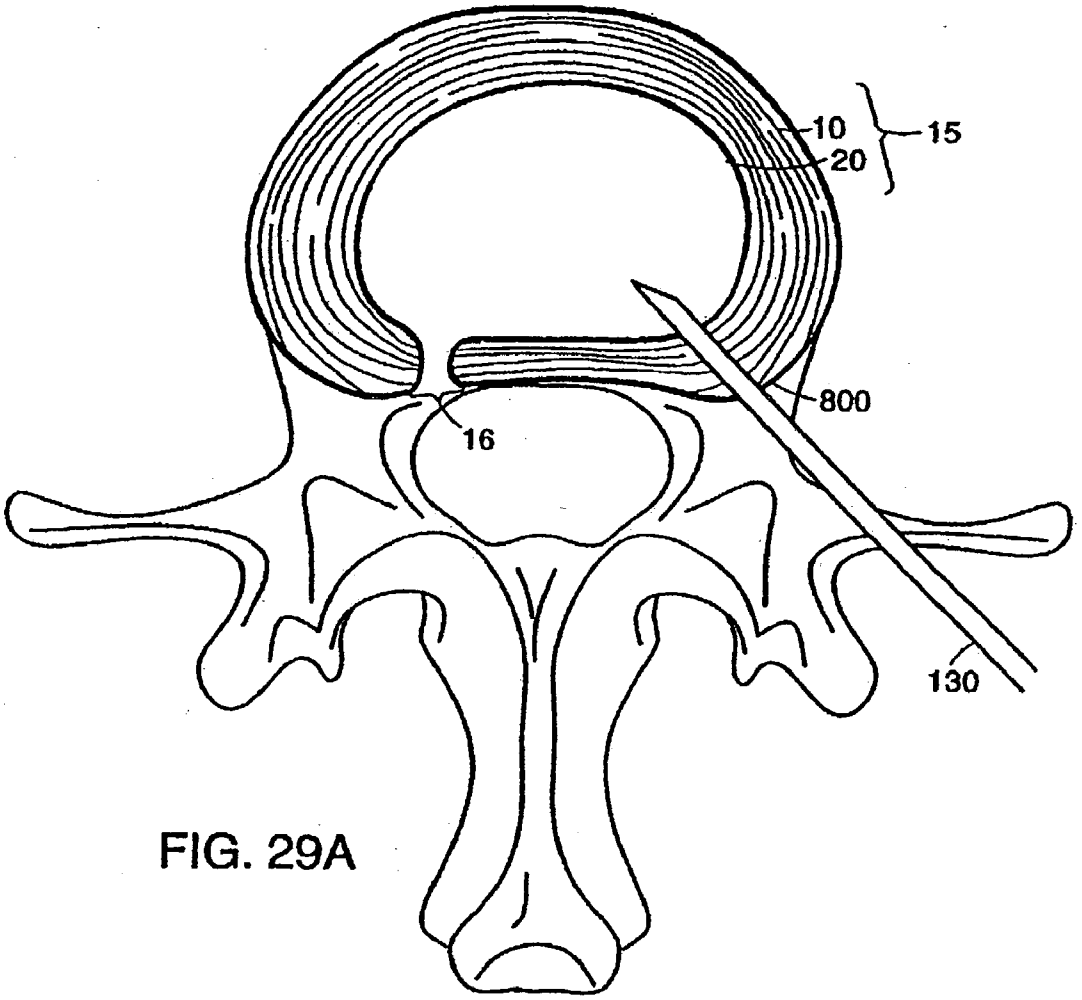


FIG. 29A

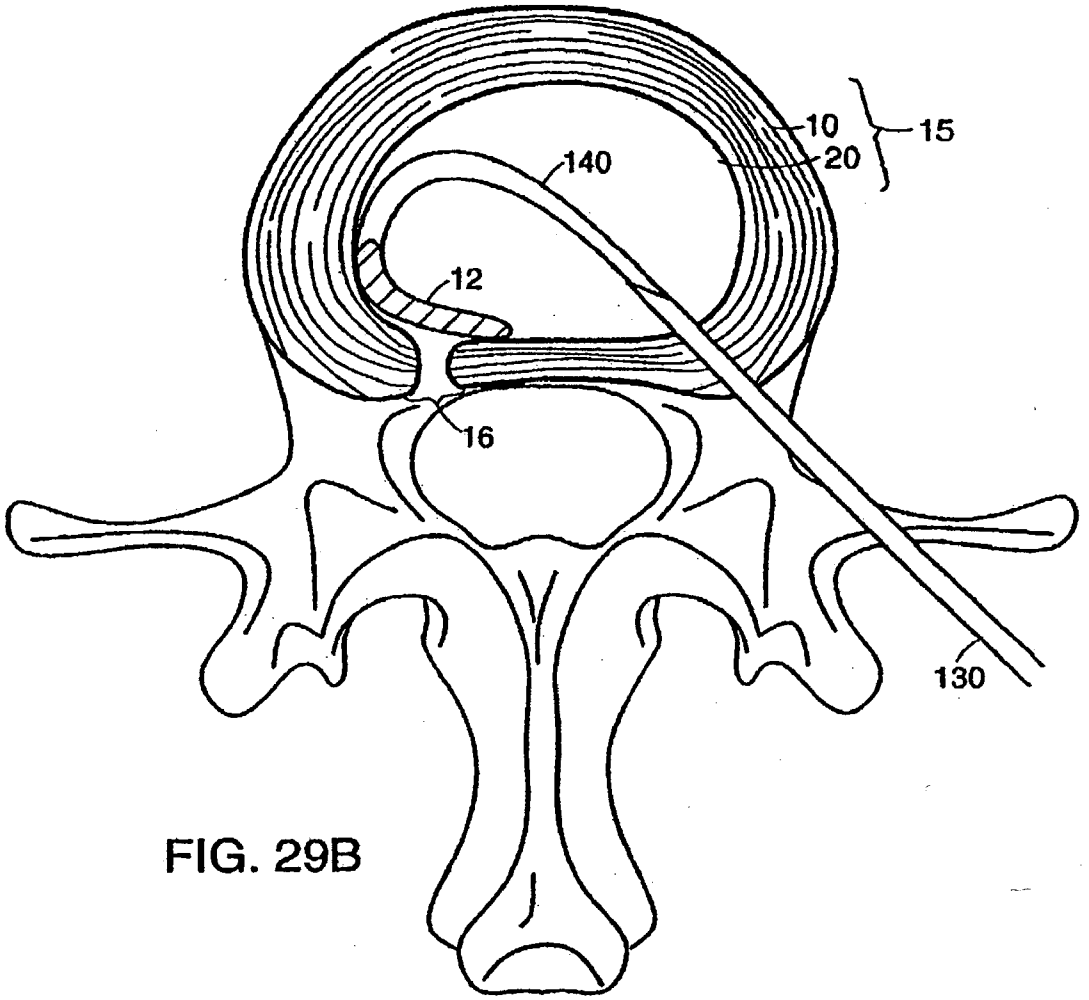


FIG. 29B

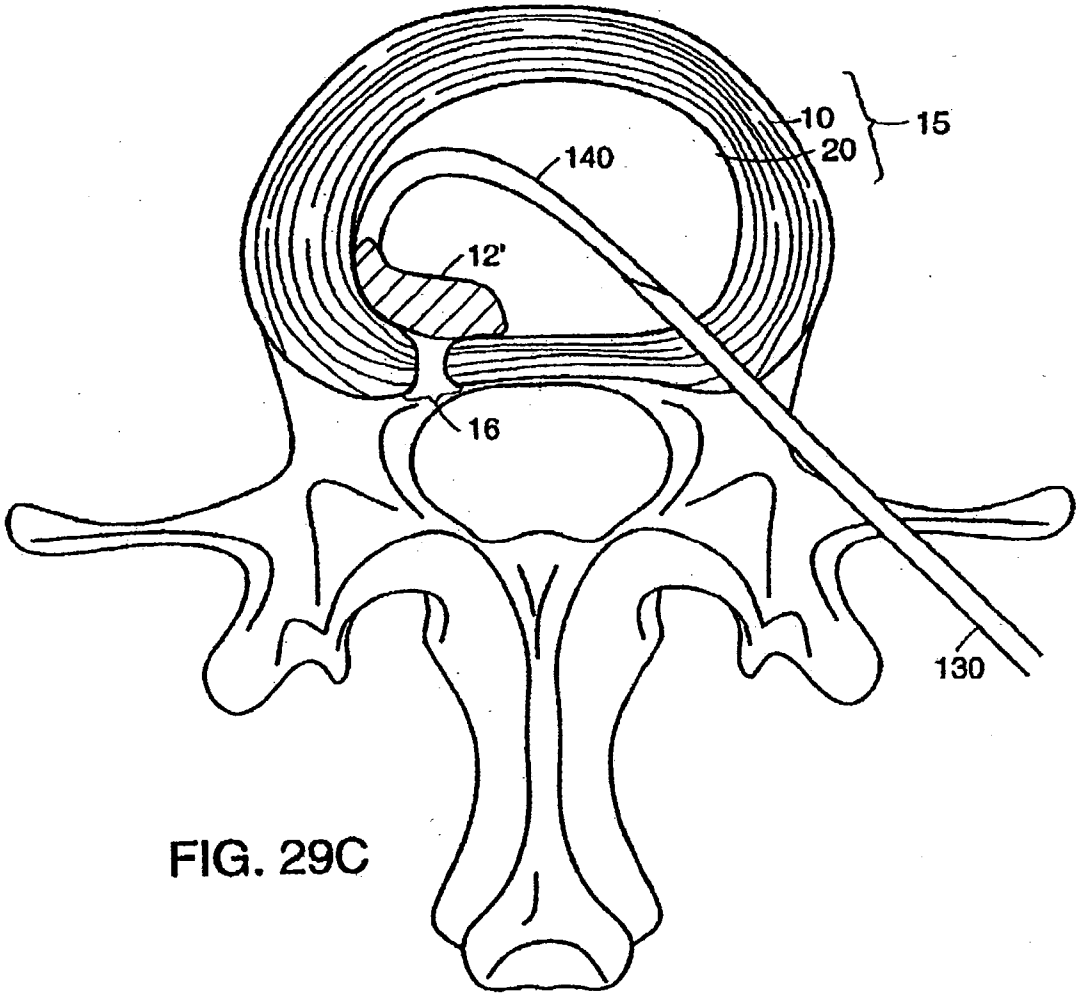


FIG. 29C

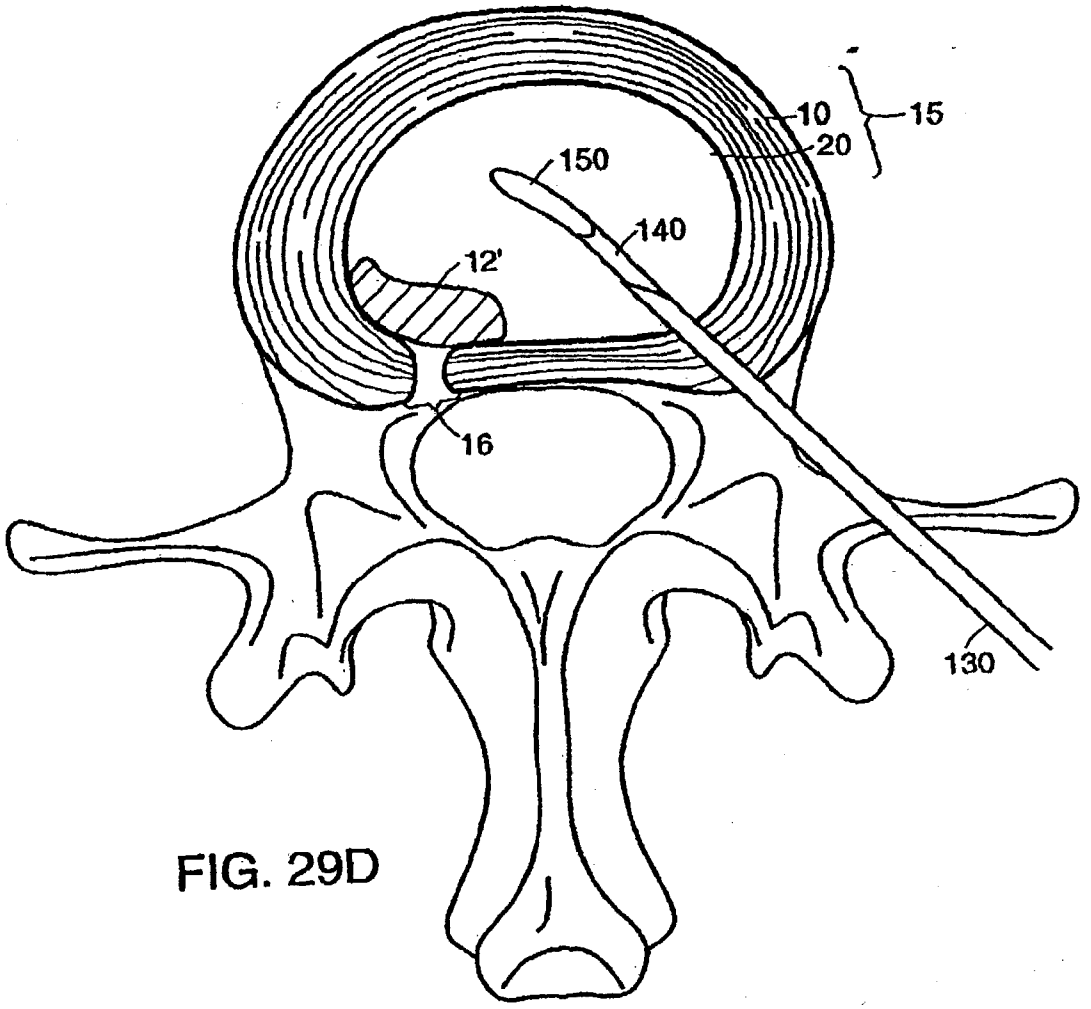


FIG. 29D

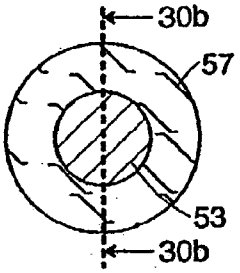


FIG. 30A

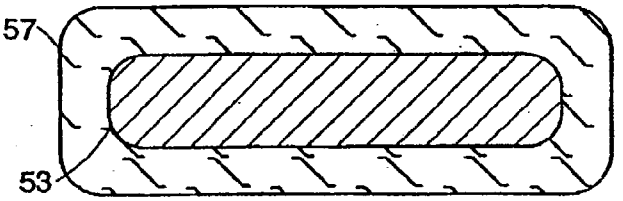


FIG. 30B

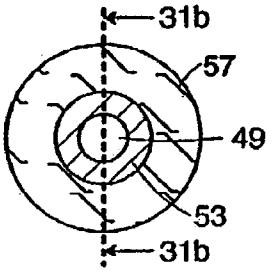


FIG. 31A

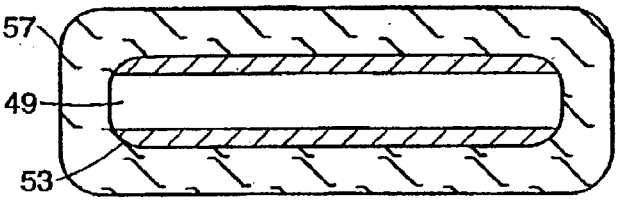


FIG. 31B

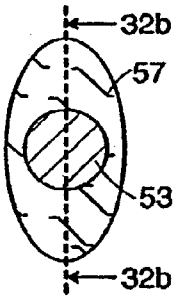


FIG. 32A

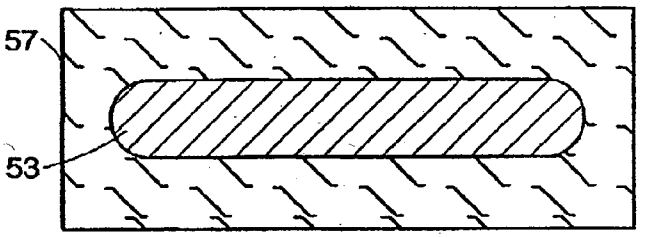


FIG. 32B

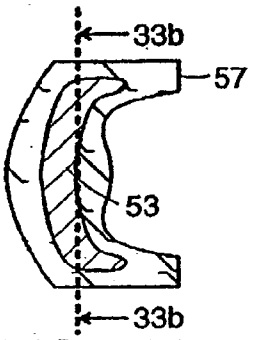


FIG. 33A

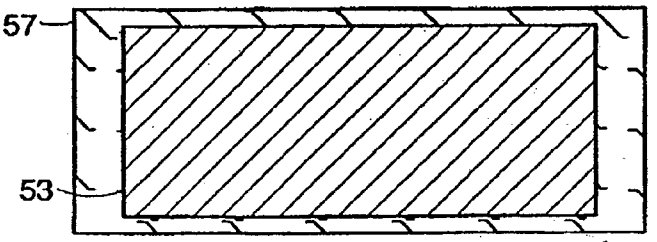


FIG. 33B

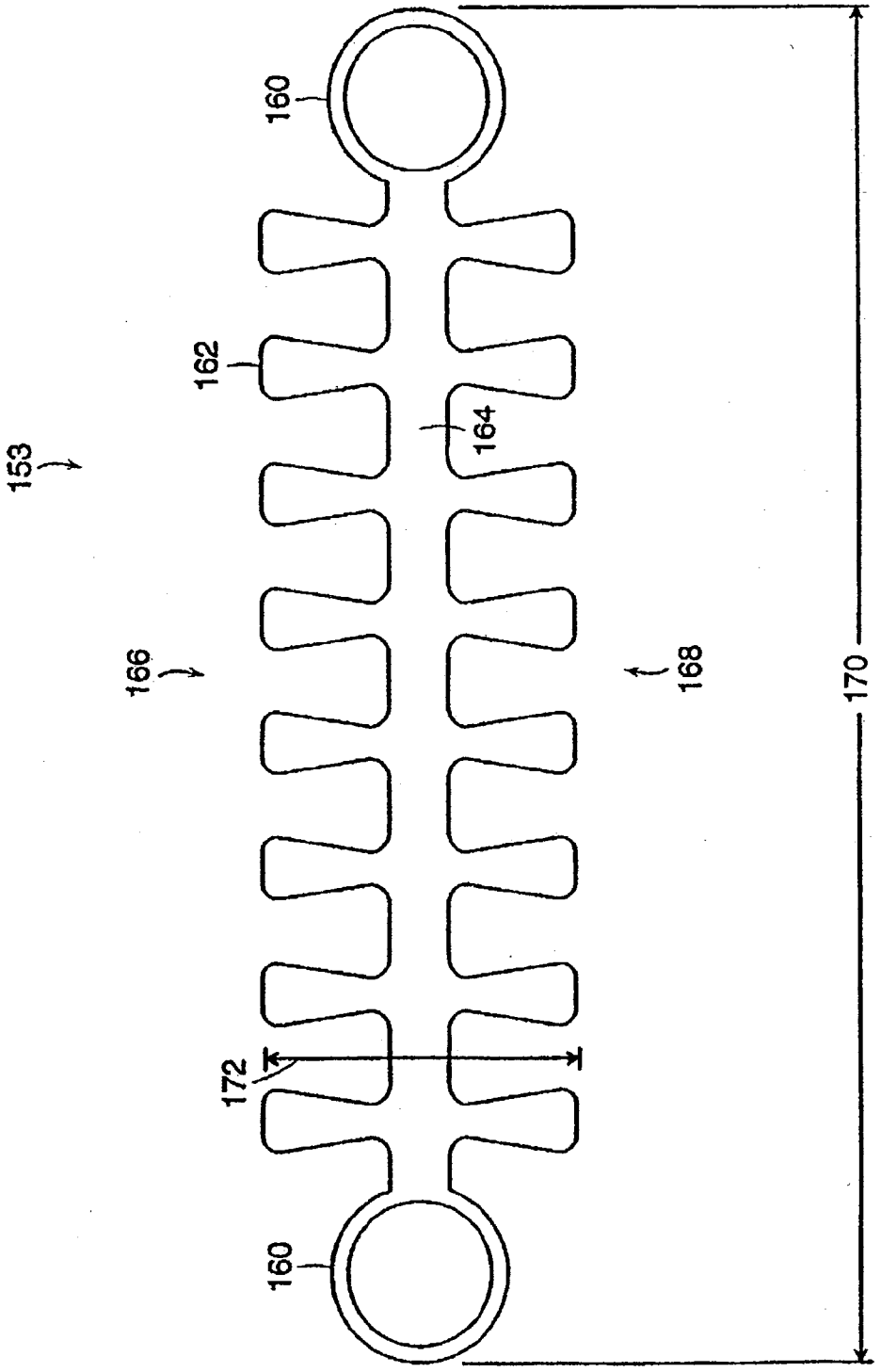


FIG. 34A

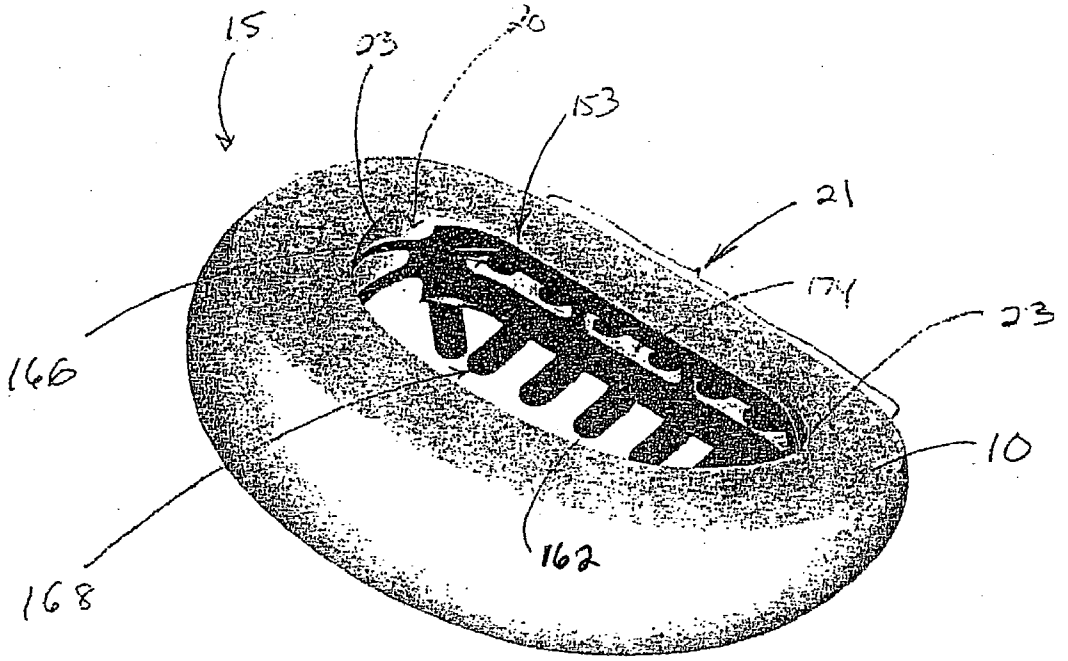


Figure 34B

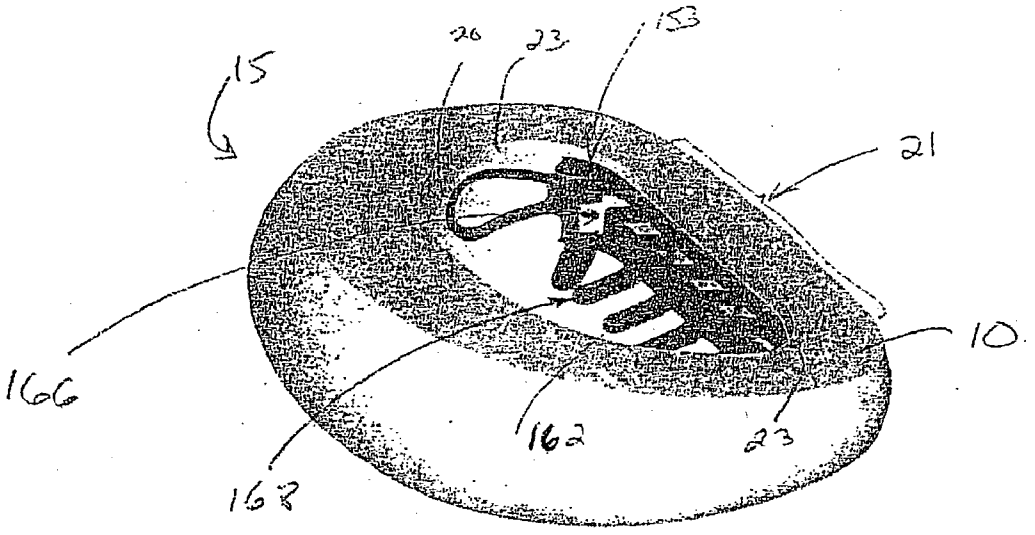


Figure 34C

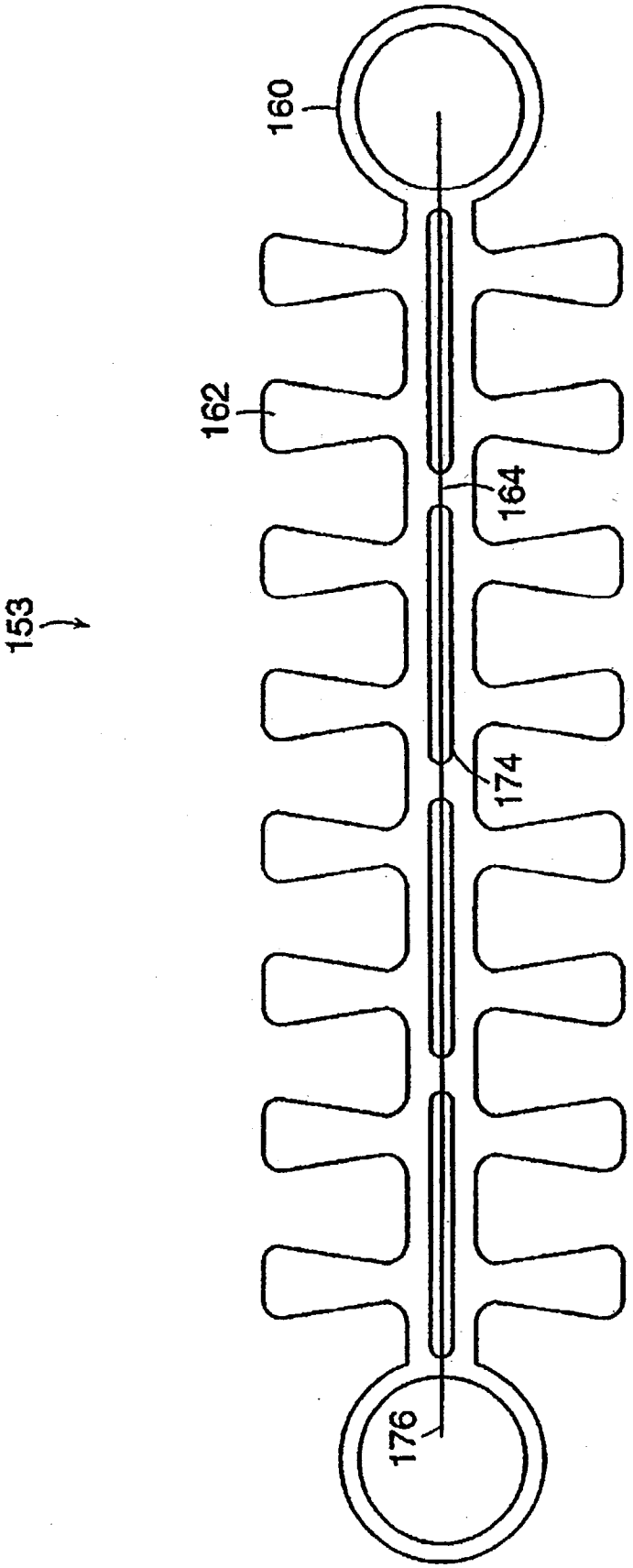


FIG. 35

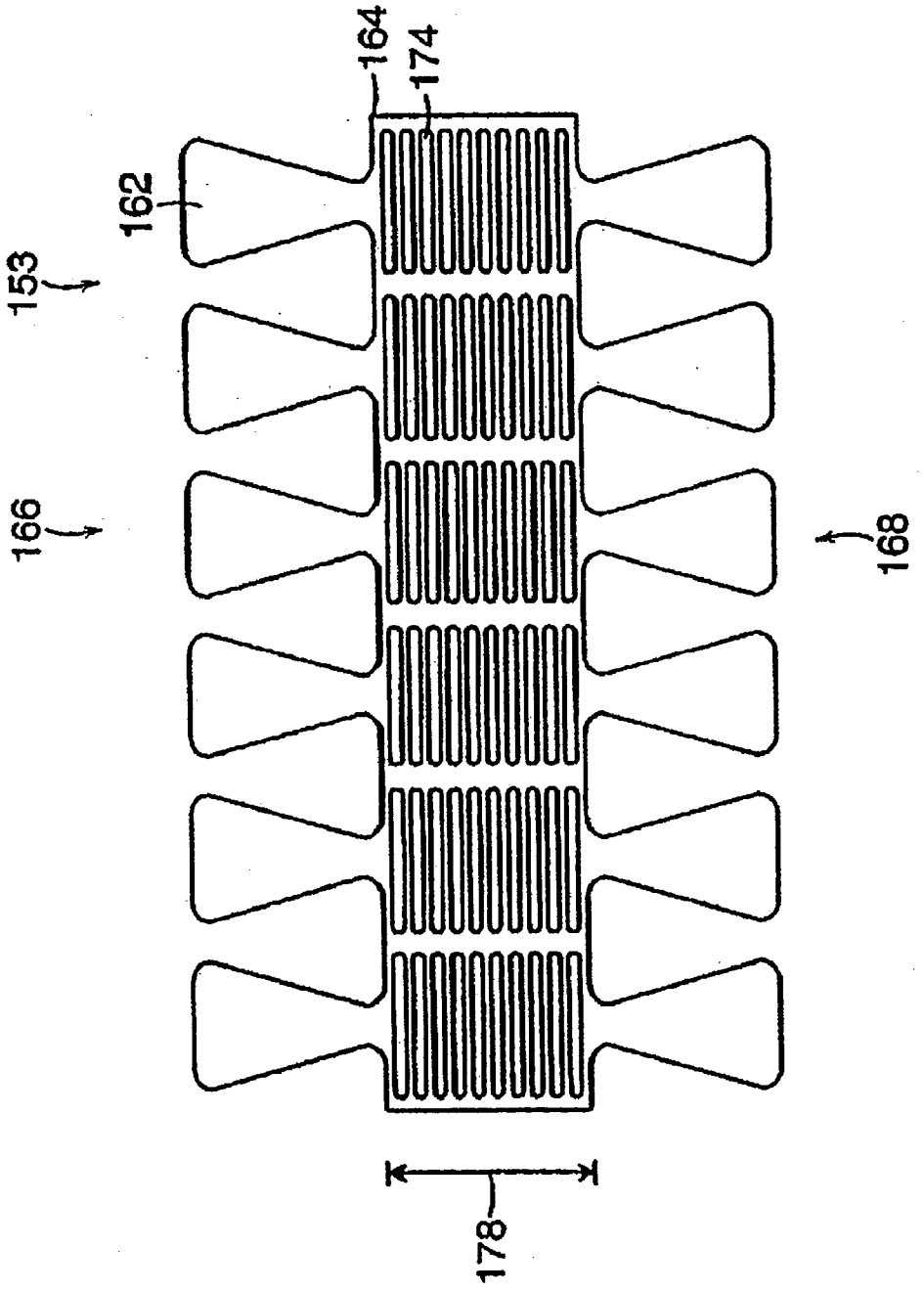


FIG. 36

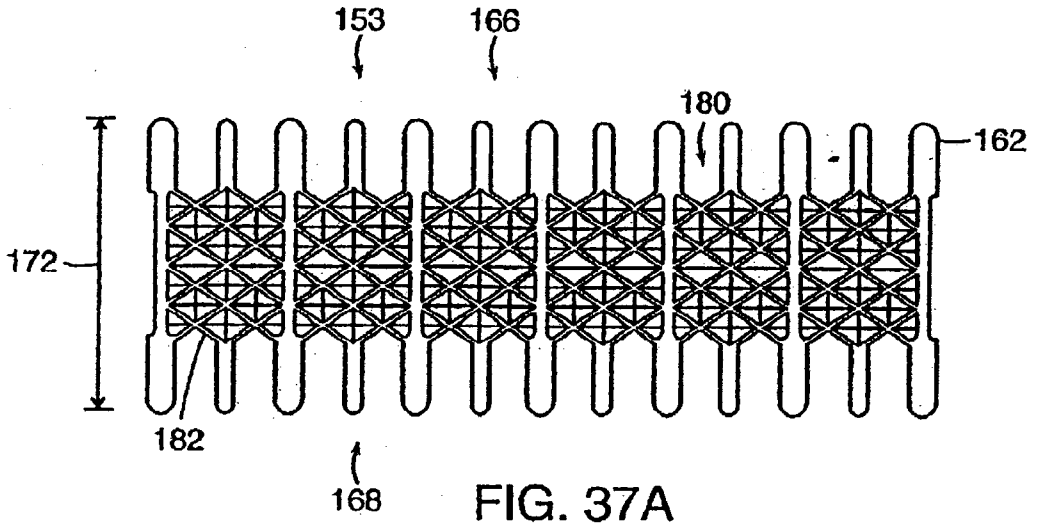


FIG. 37A

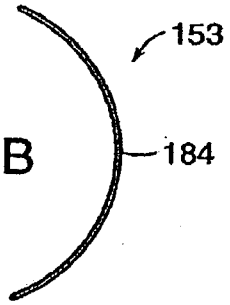


FIG. 37B

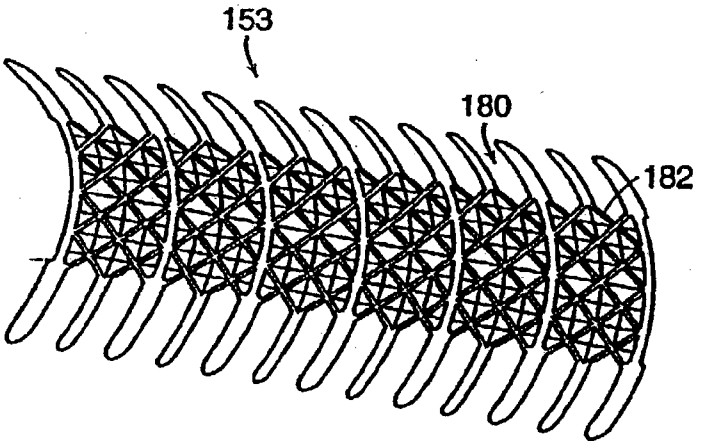


FIG. 37C

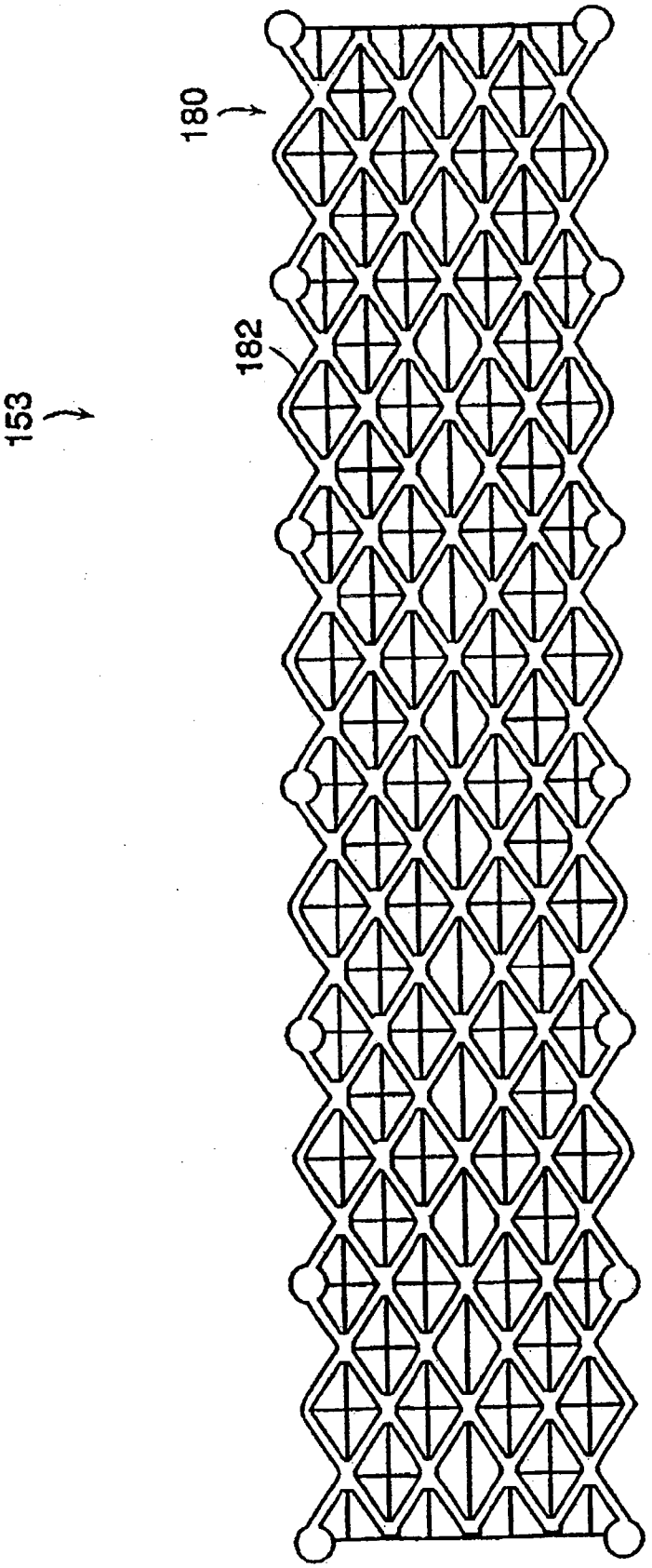


FIG. 38

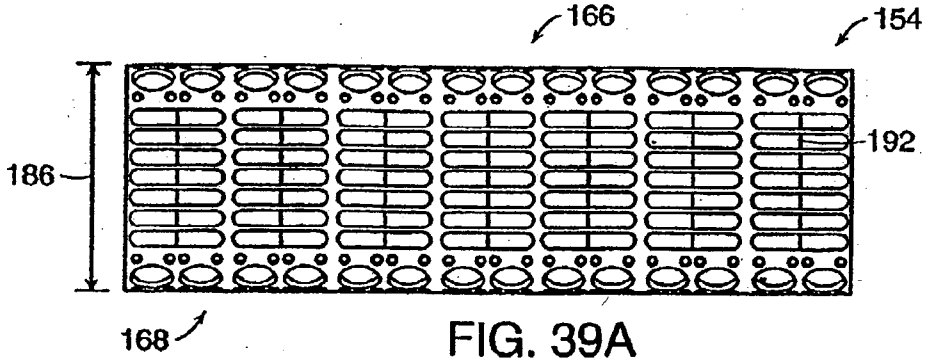


FIG. 39A

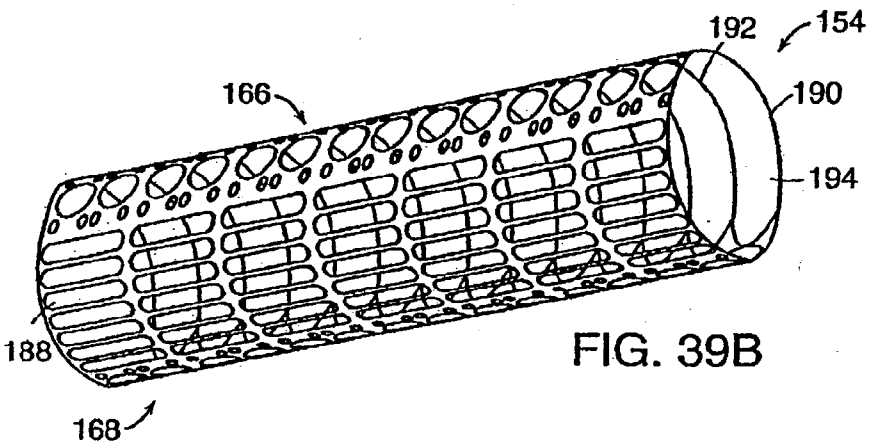


FIG. 39B

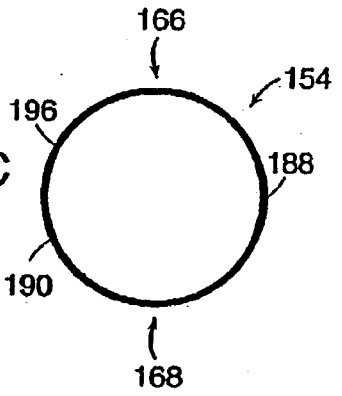


FIG. 39C

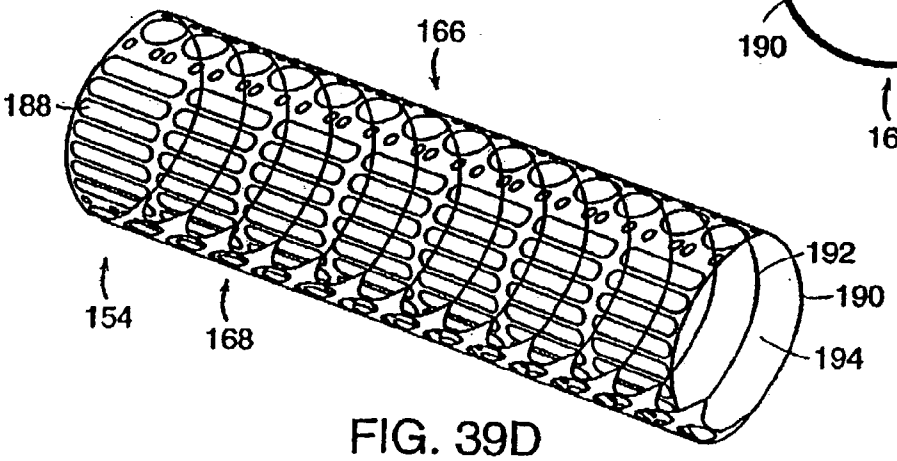


FIG. 39D

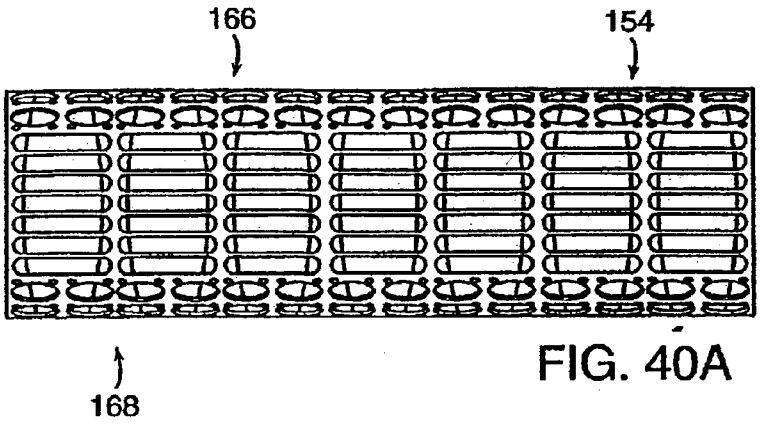


FIG. 40A

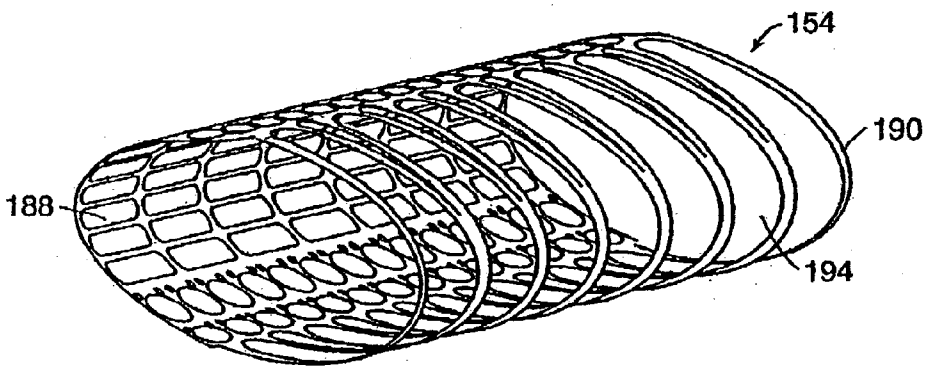


FIG. 40B

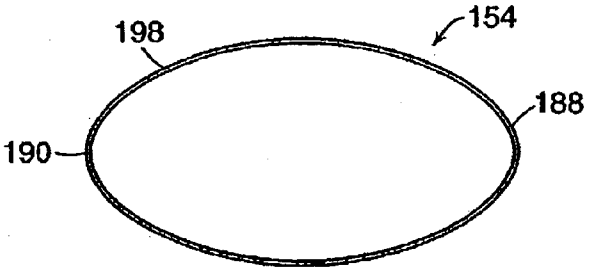


FIG. 40C

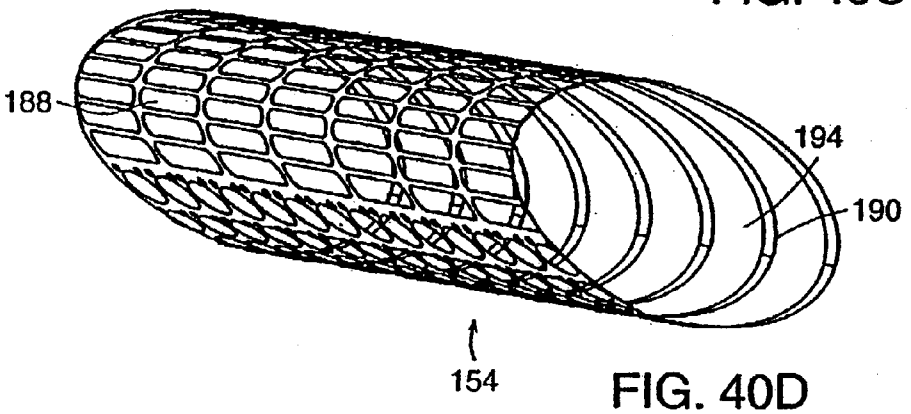


FIG. 40D

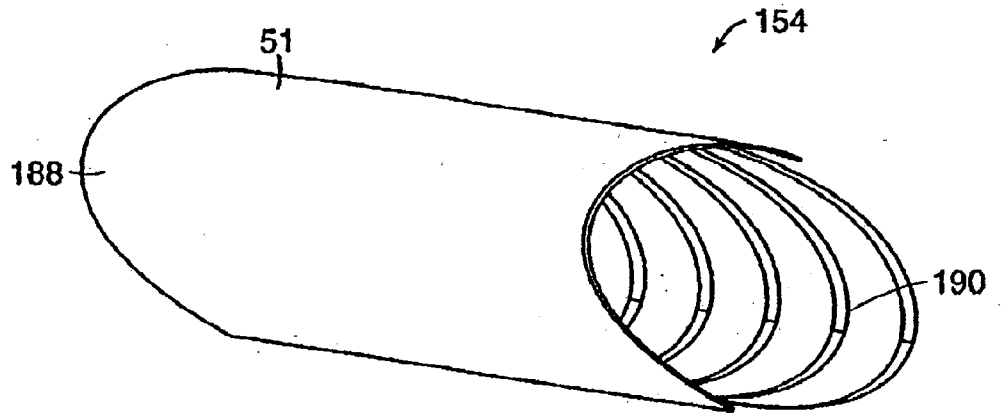


FIG. 40E

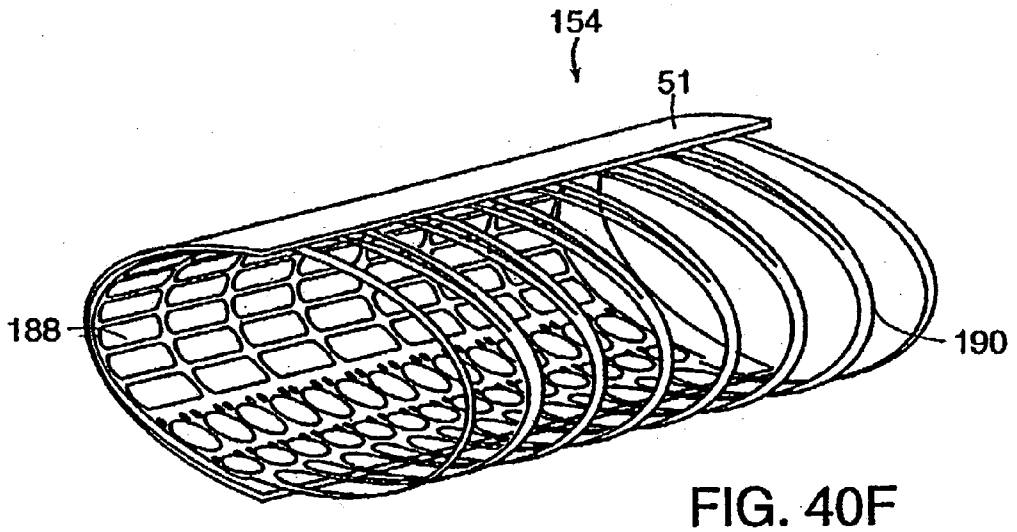


FIG. 40F

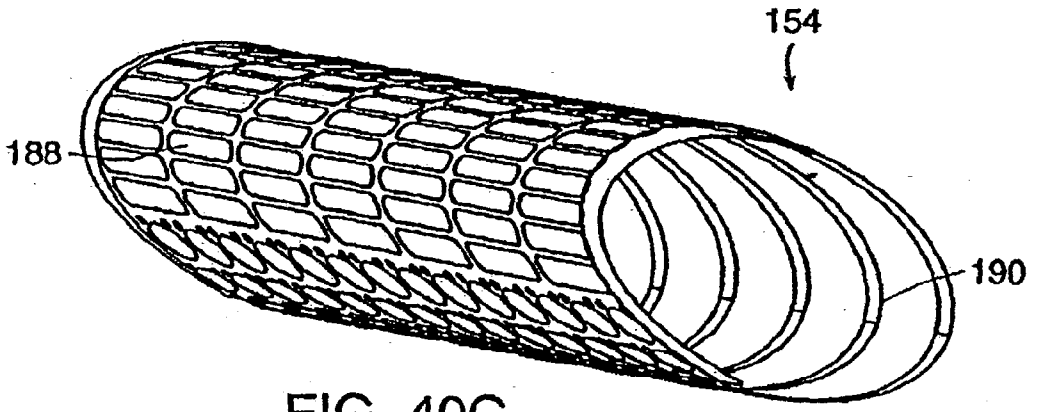


FIG. 40G

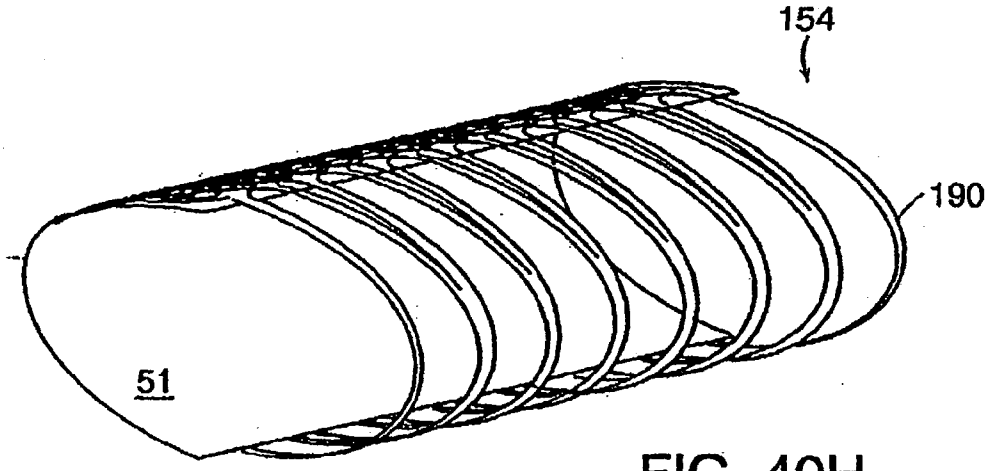


FIG. 40H

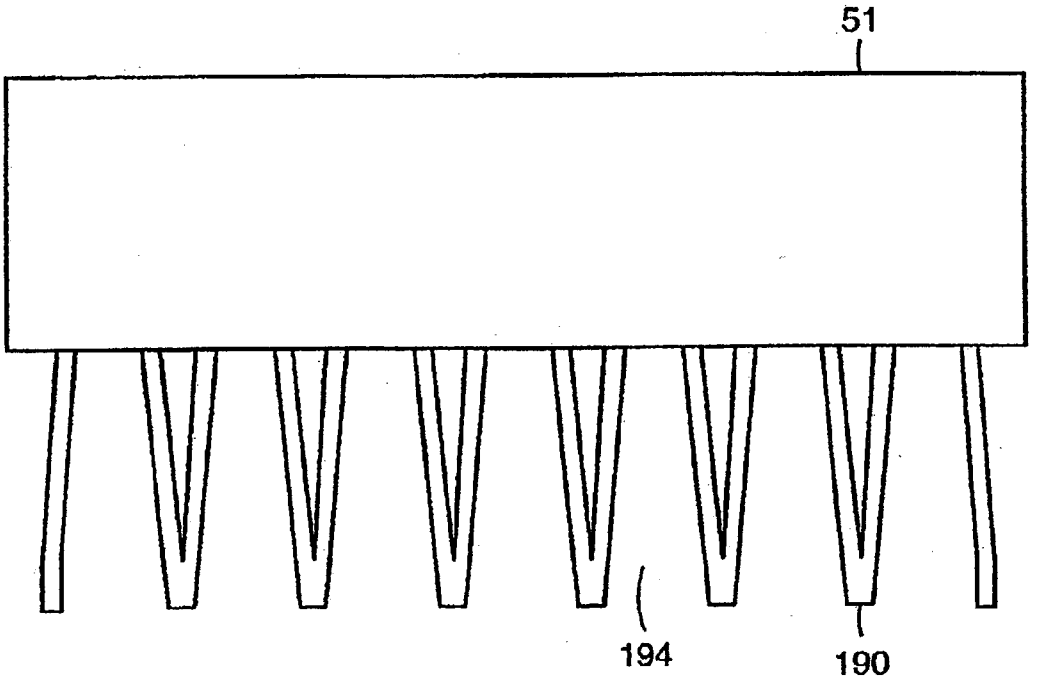


FIG. 40I

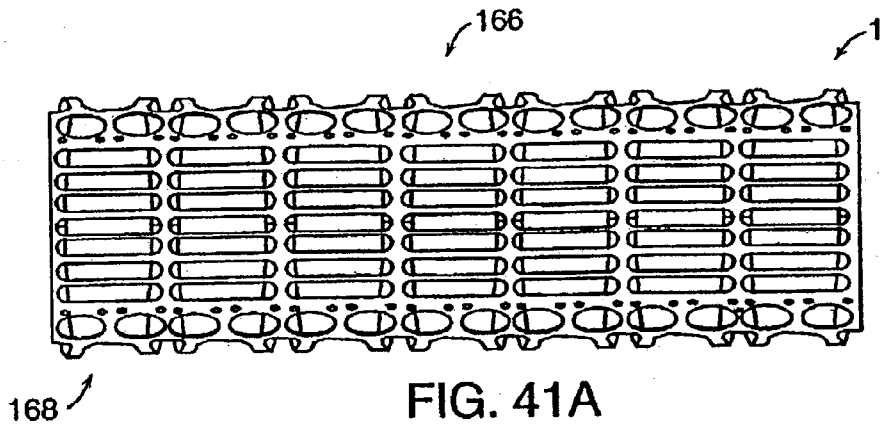


FIG. 41A

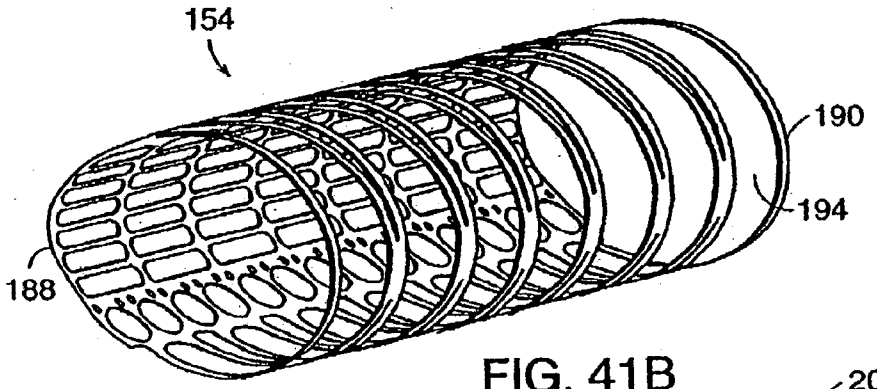


FIG. 41B

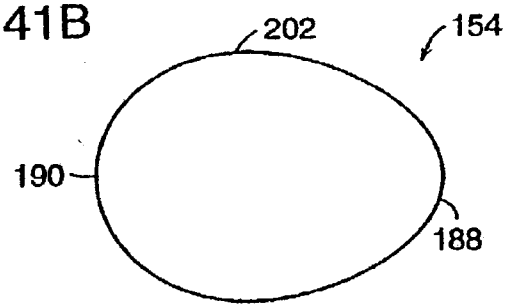


FIG. 41C

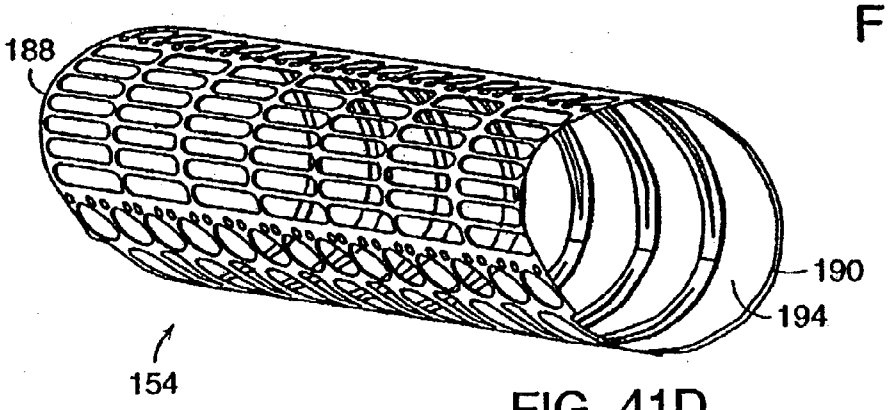


FIG. 41D

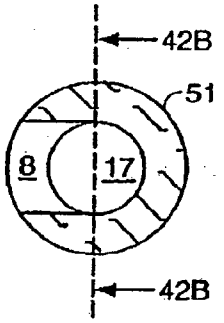


FIG. 42A

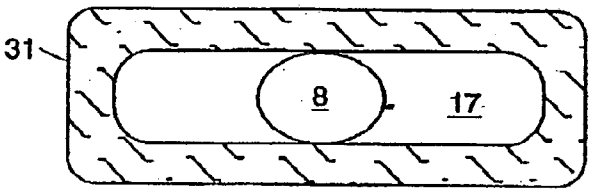


FIG. 42B

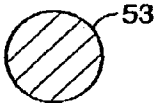


FIG. 42C

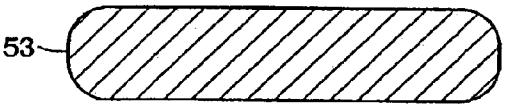


FIG. 42D

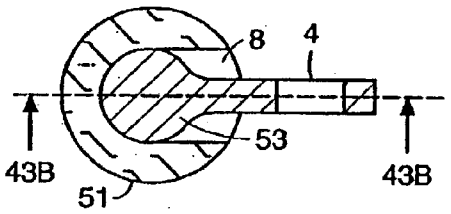


FIG. 43A

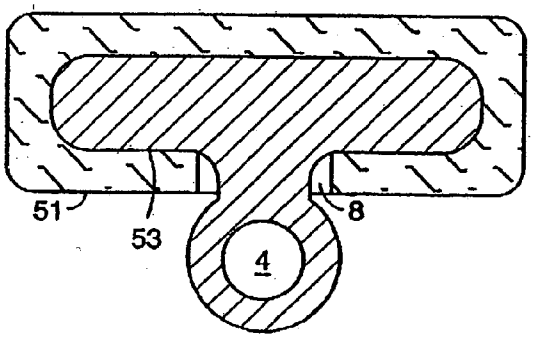


FIG. 43B

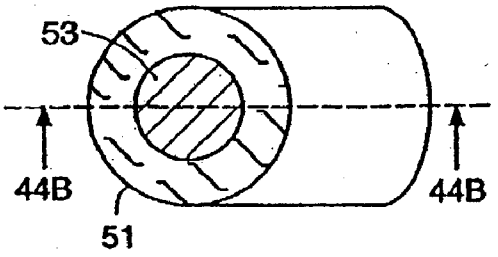


FIG. 44A

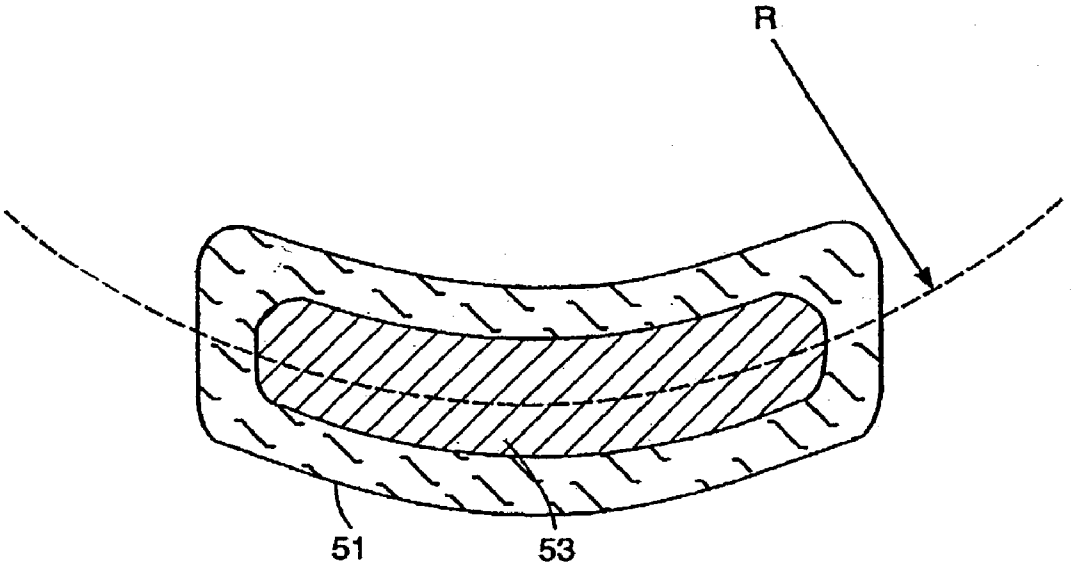


FIG. 44B

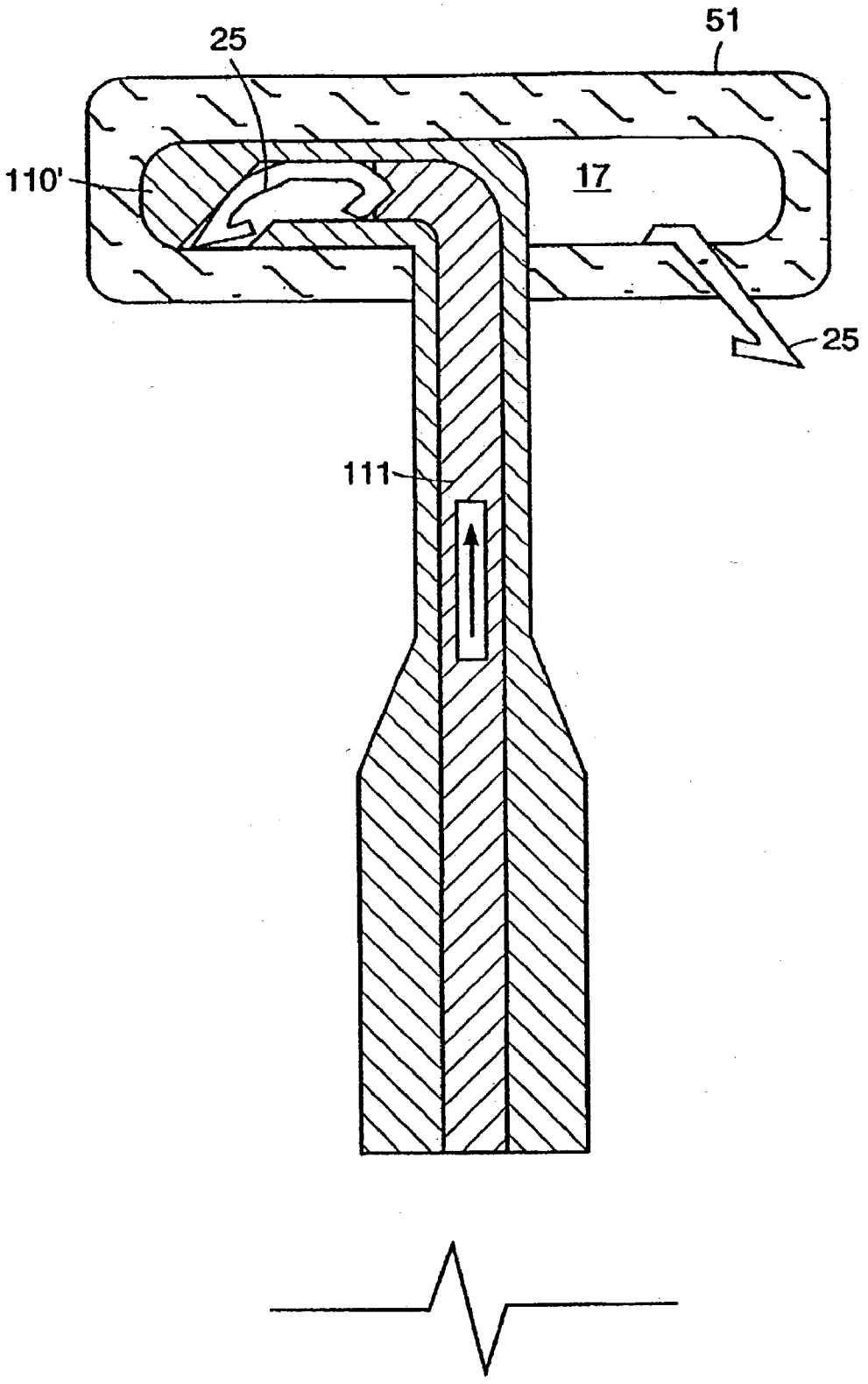


FIG. 45

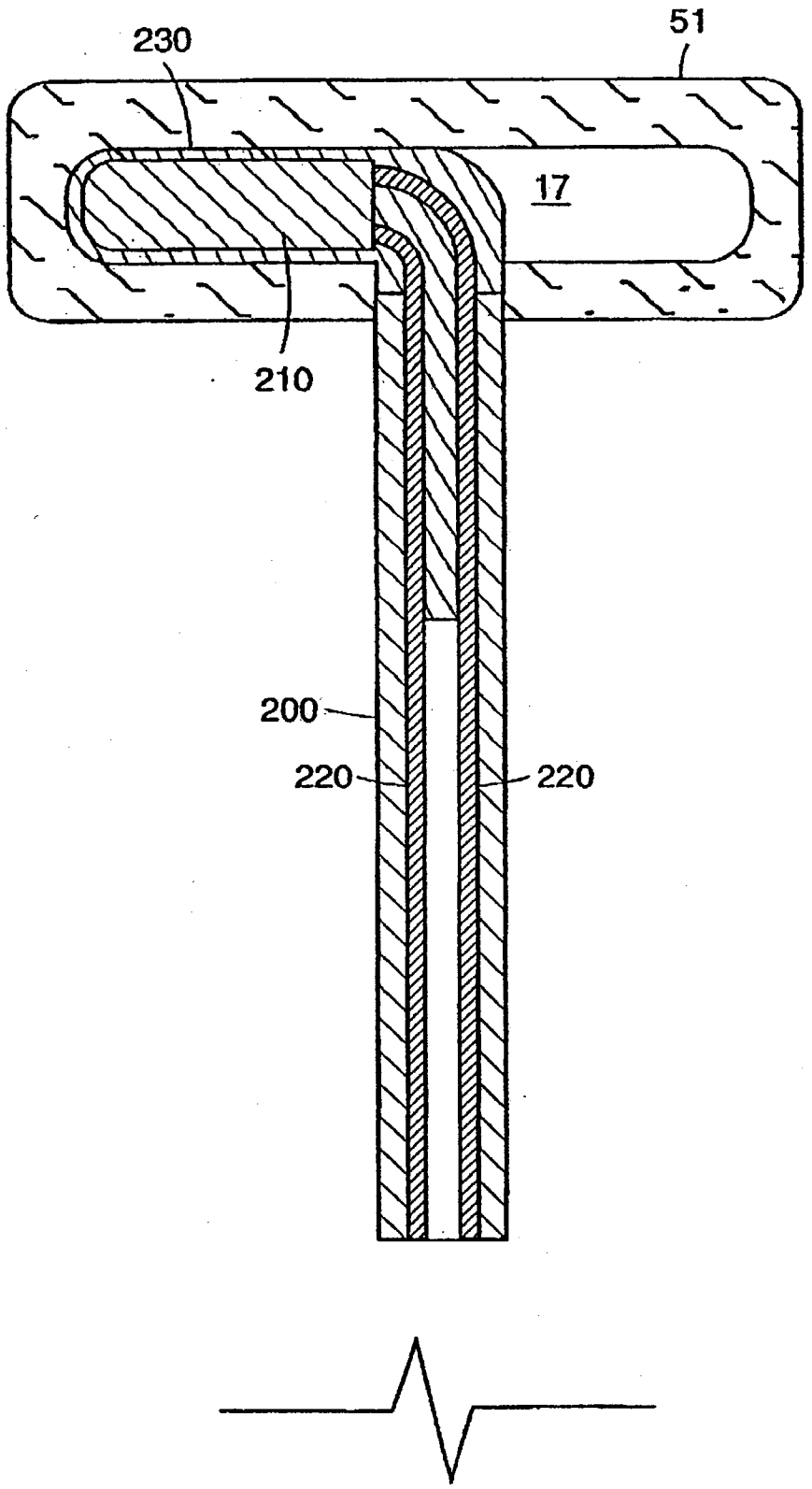


FIG. 46

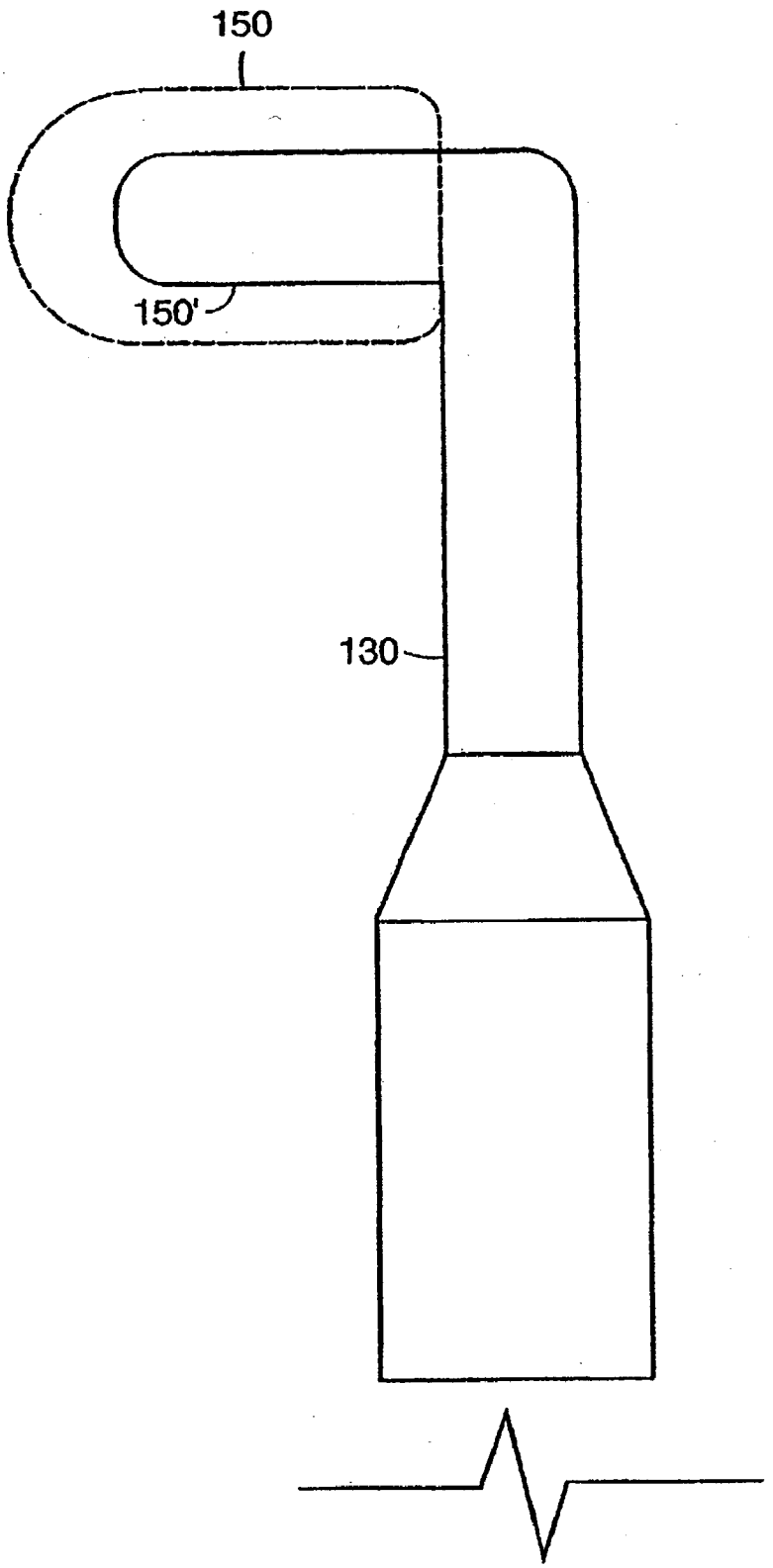


FIG. 47

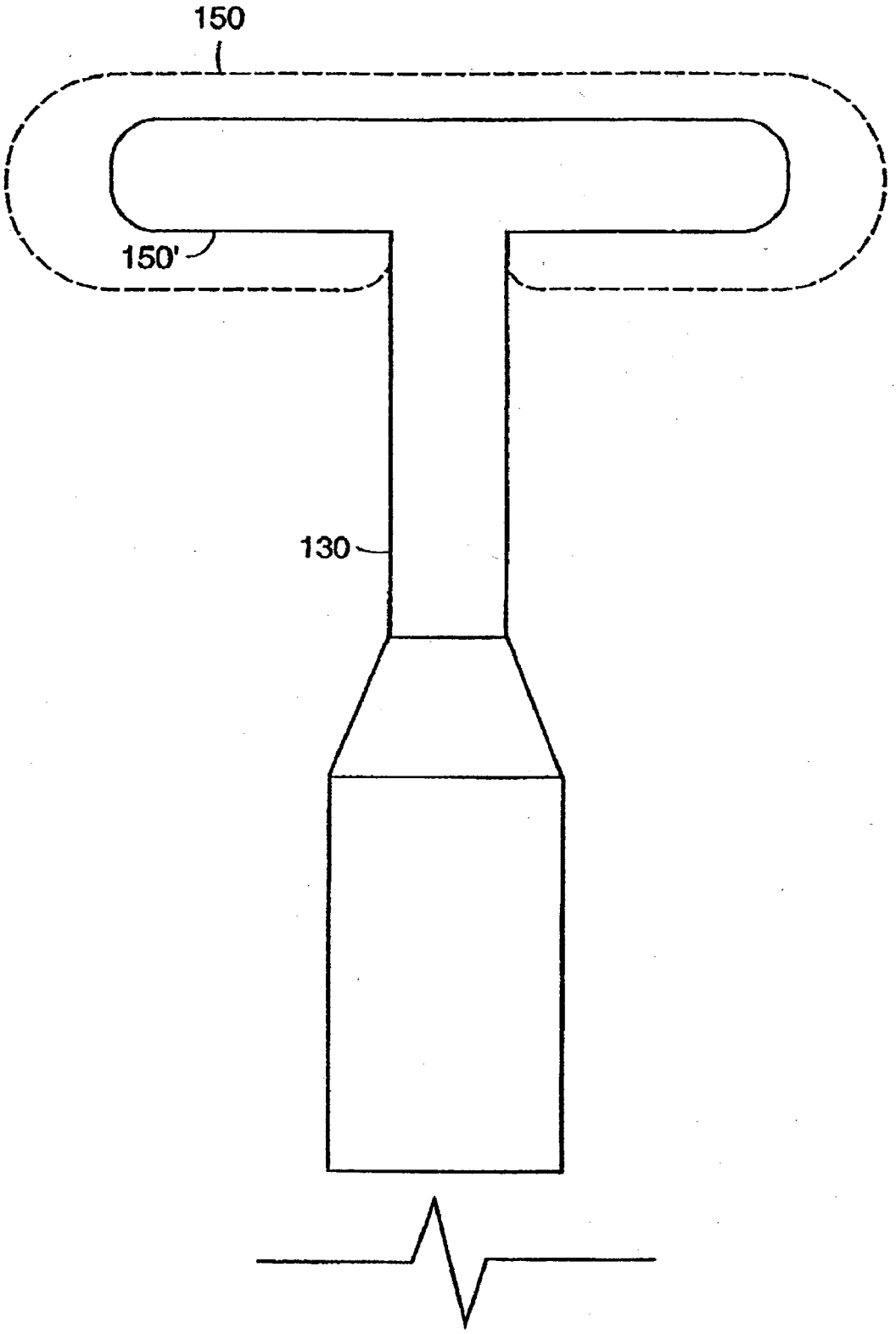


FIG. 48

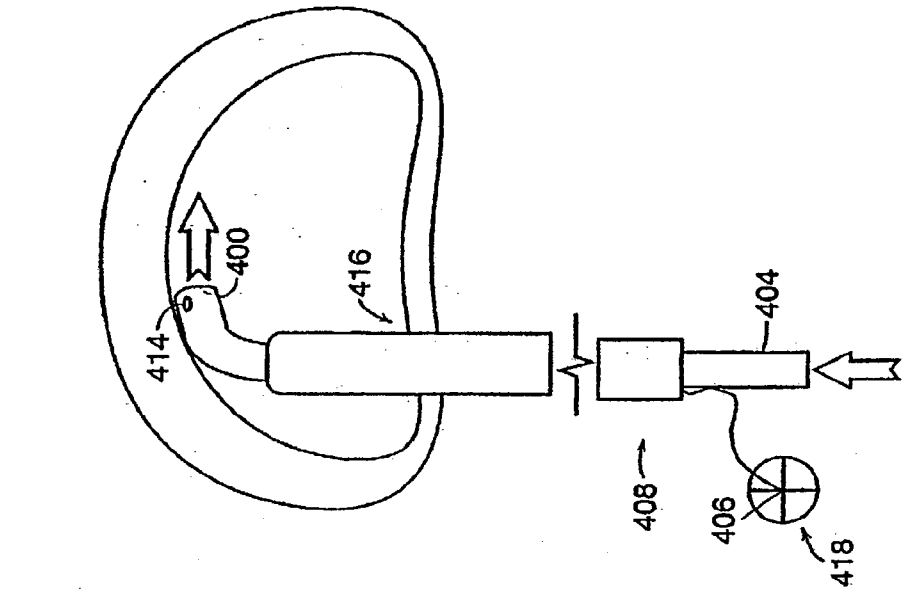


FIG. 49B

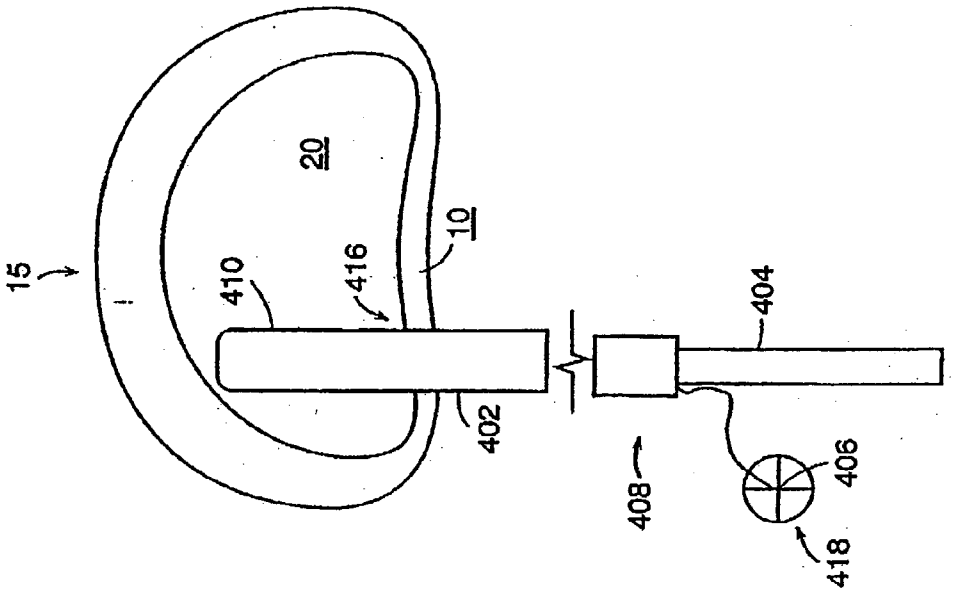


FIG. 49A

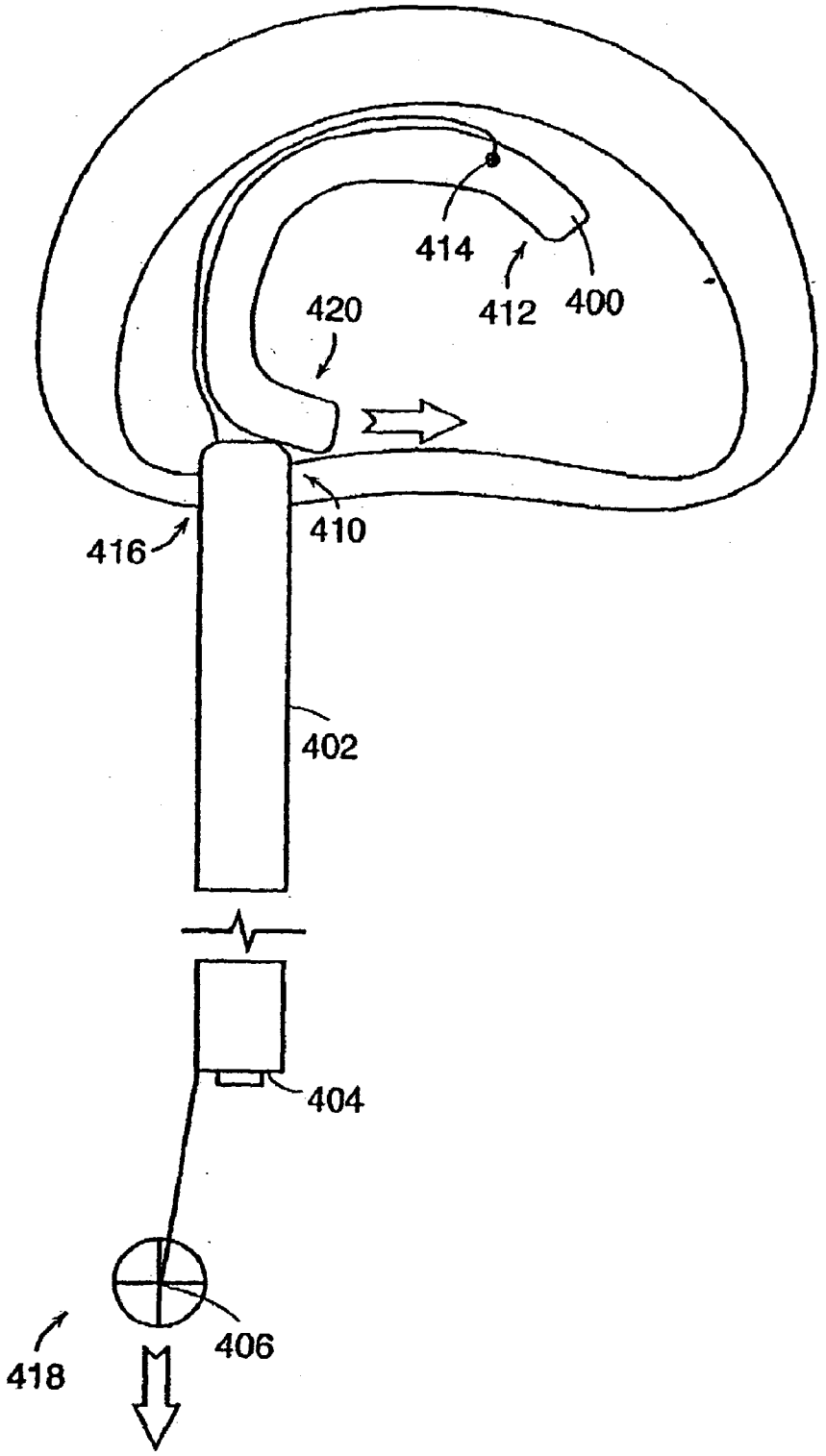


FIG. 49C

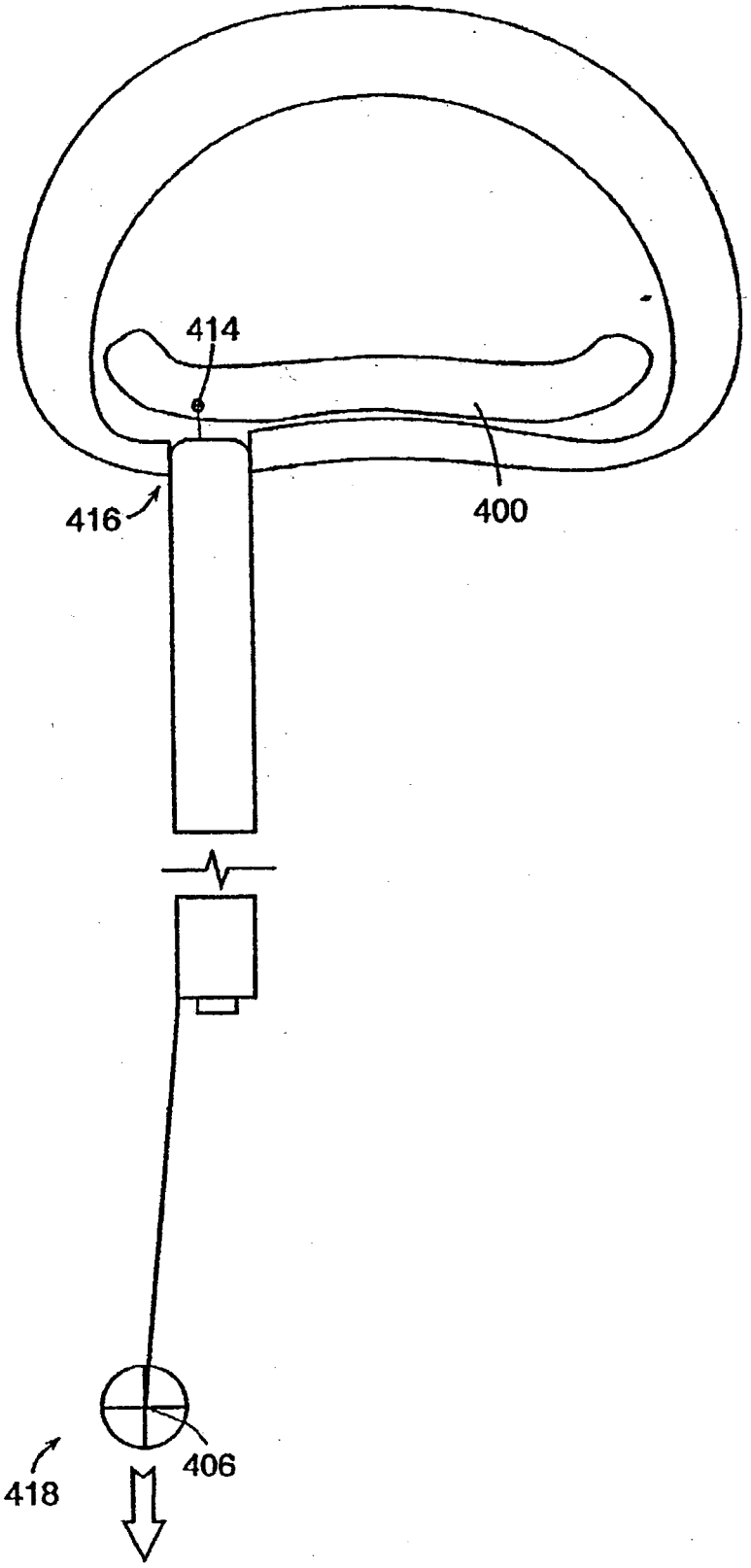


FIG. 49D

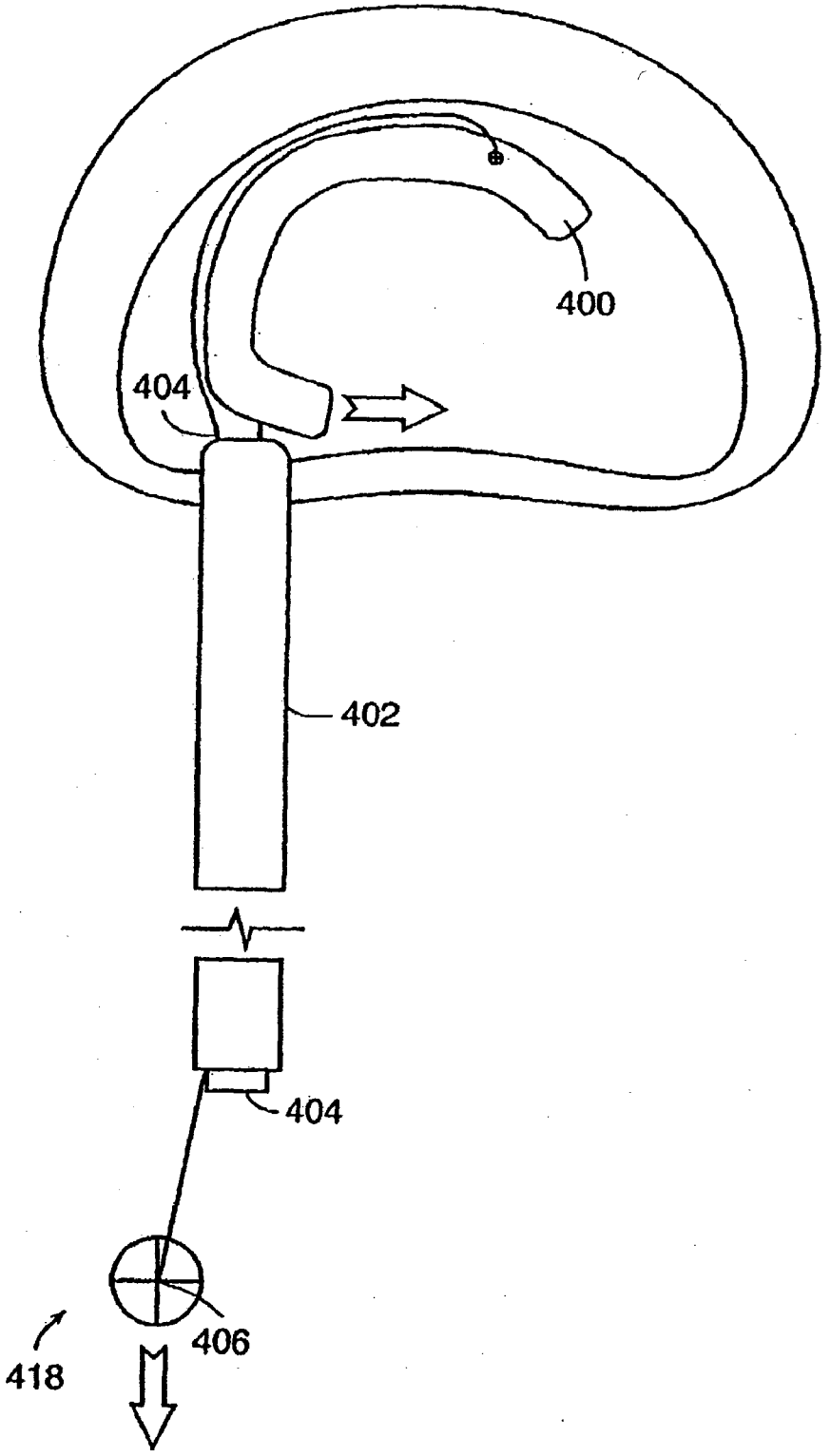


FIG. 49E

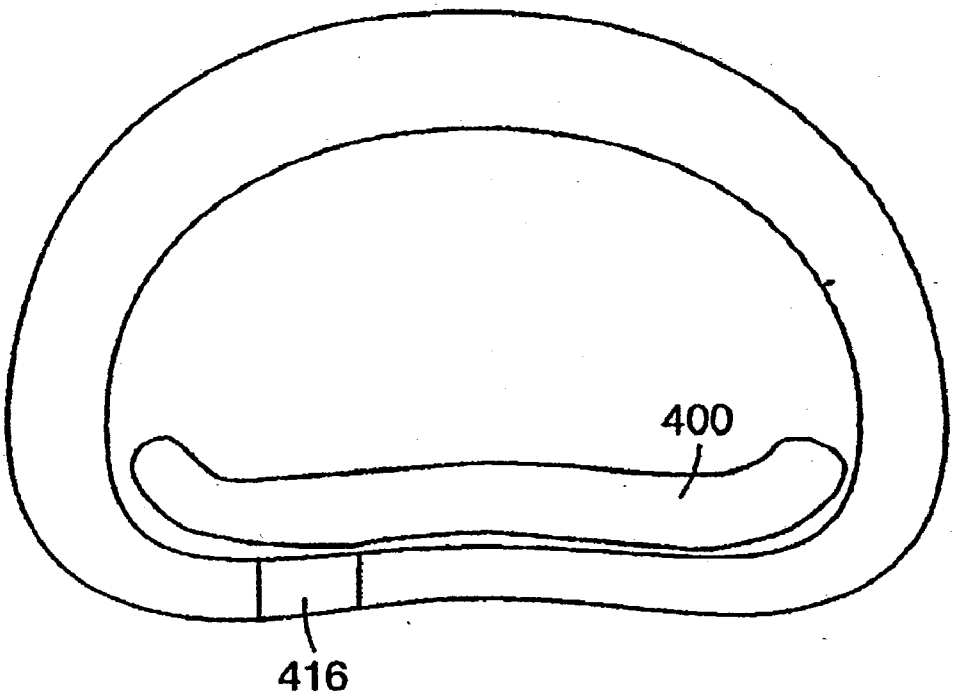


FIG. 49F

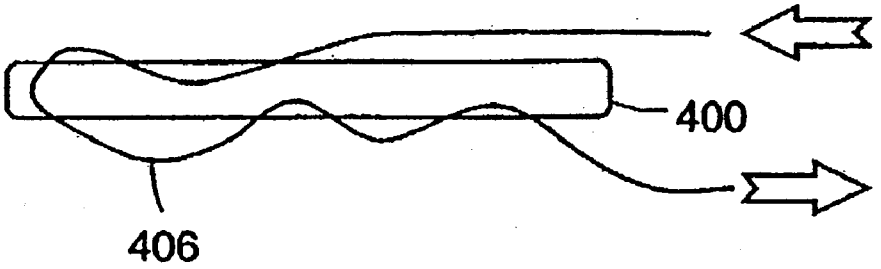


FIG. 49G

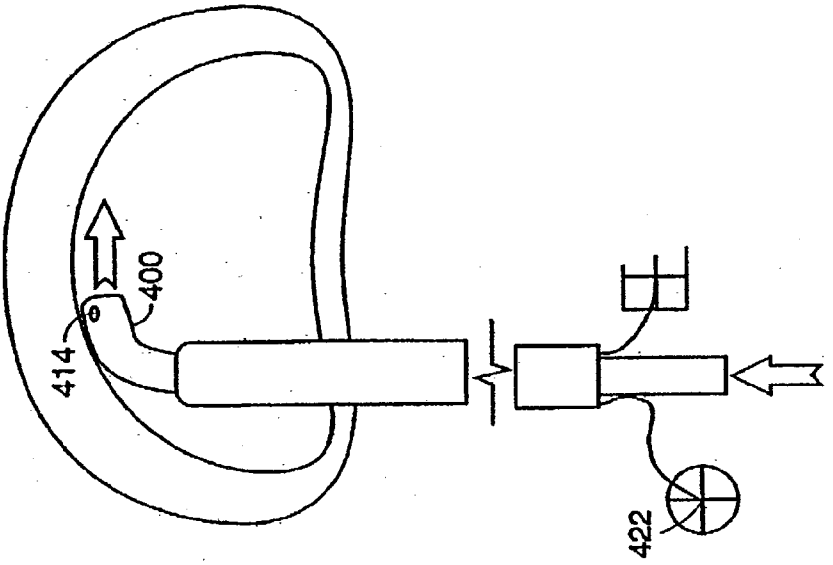


FIG. 50B

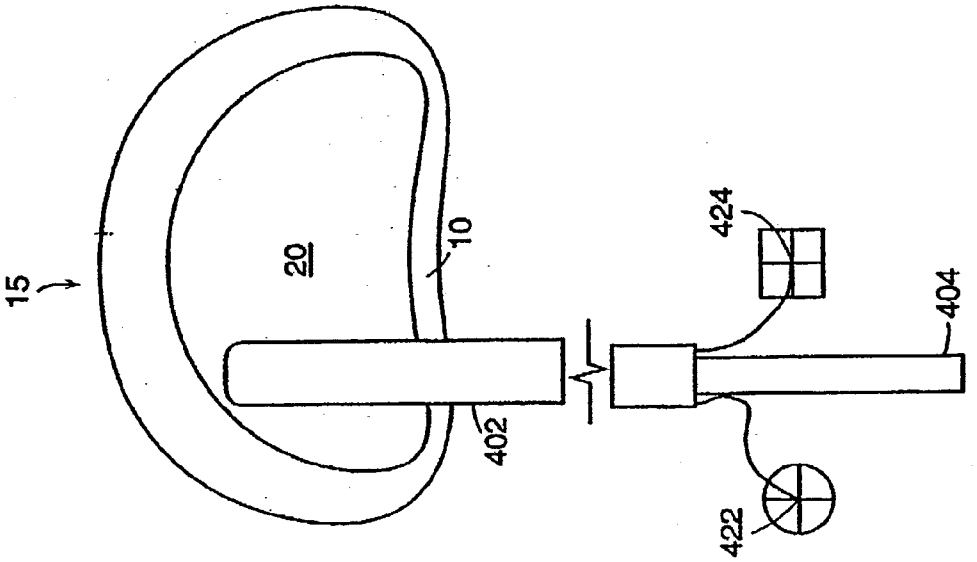


FIG. 50A

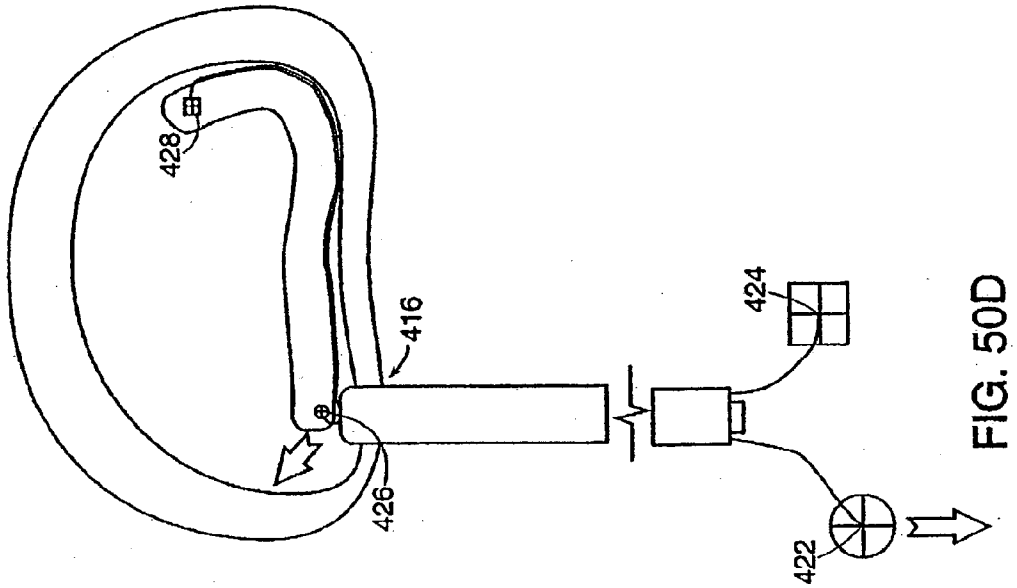


FIG. 50D

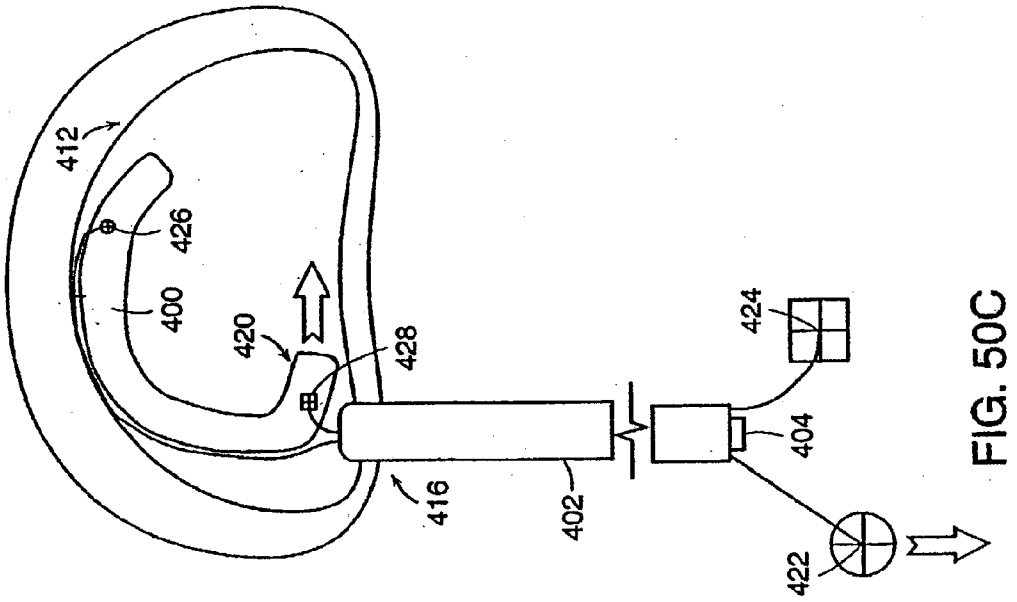


FIG. 50C

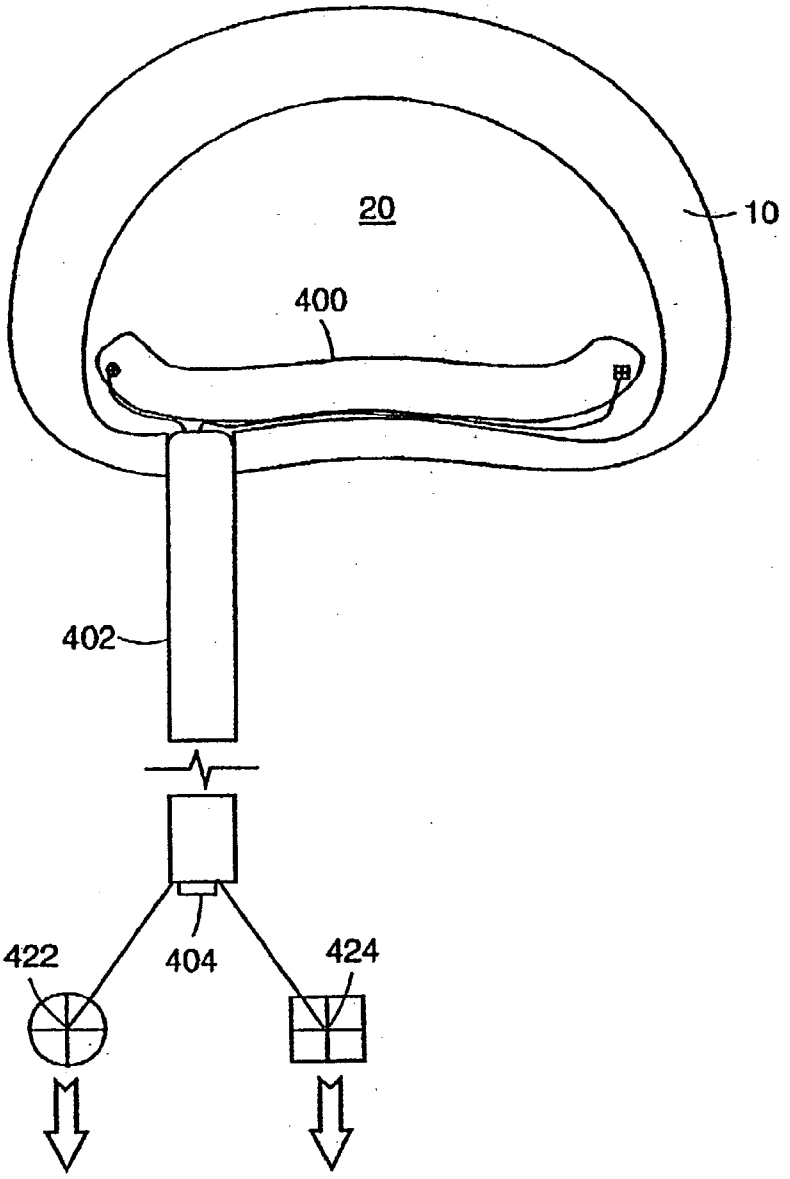


FIG. 50E

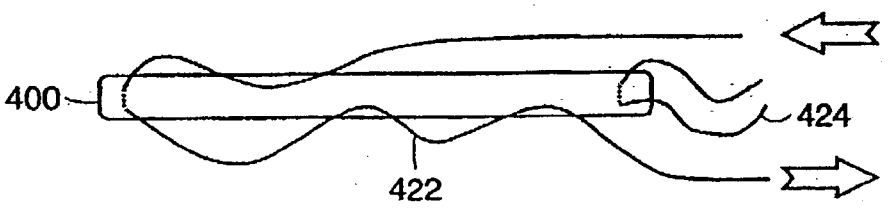


FIG. 50F

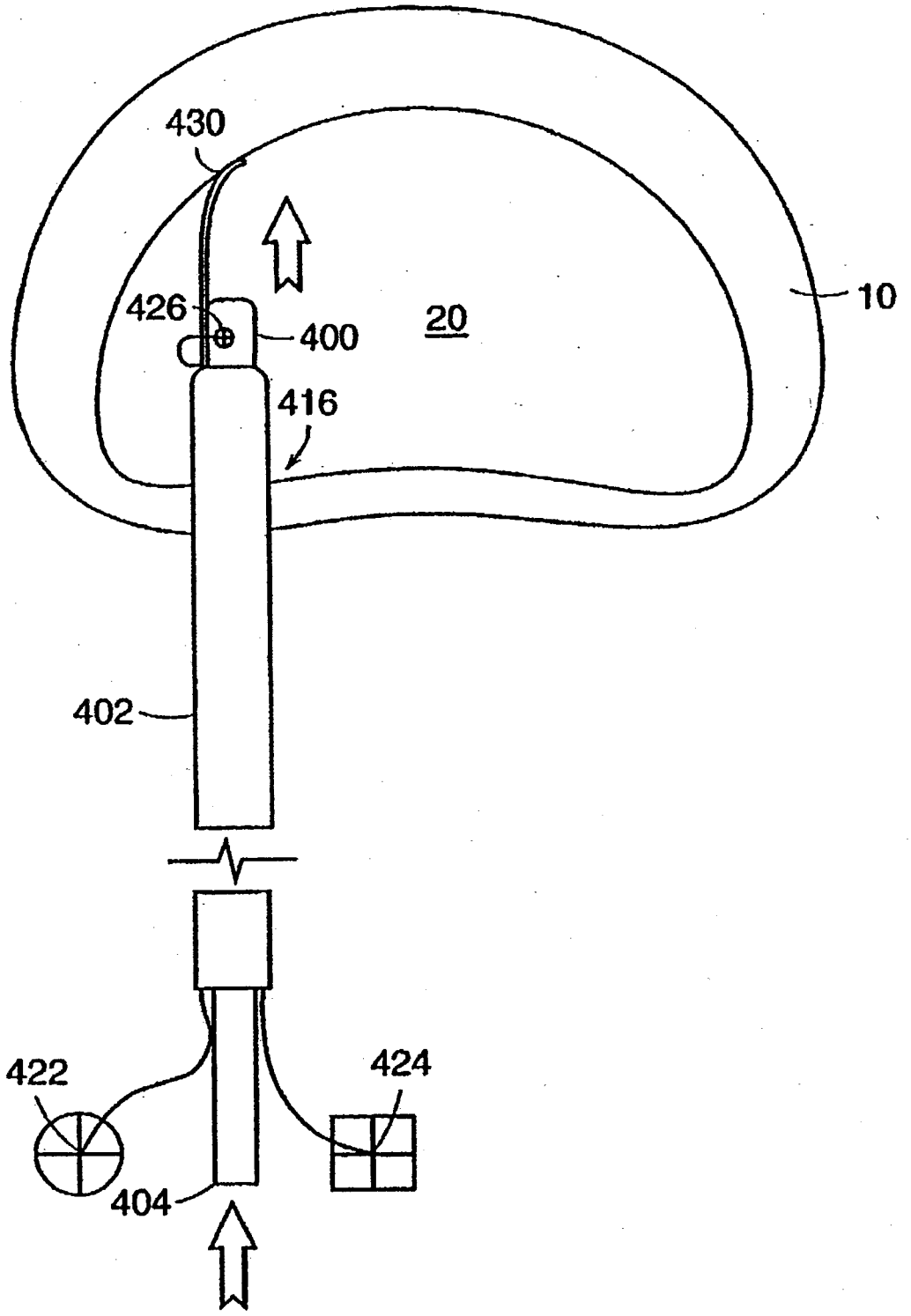


FIG. 51A

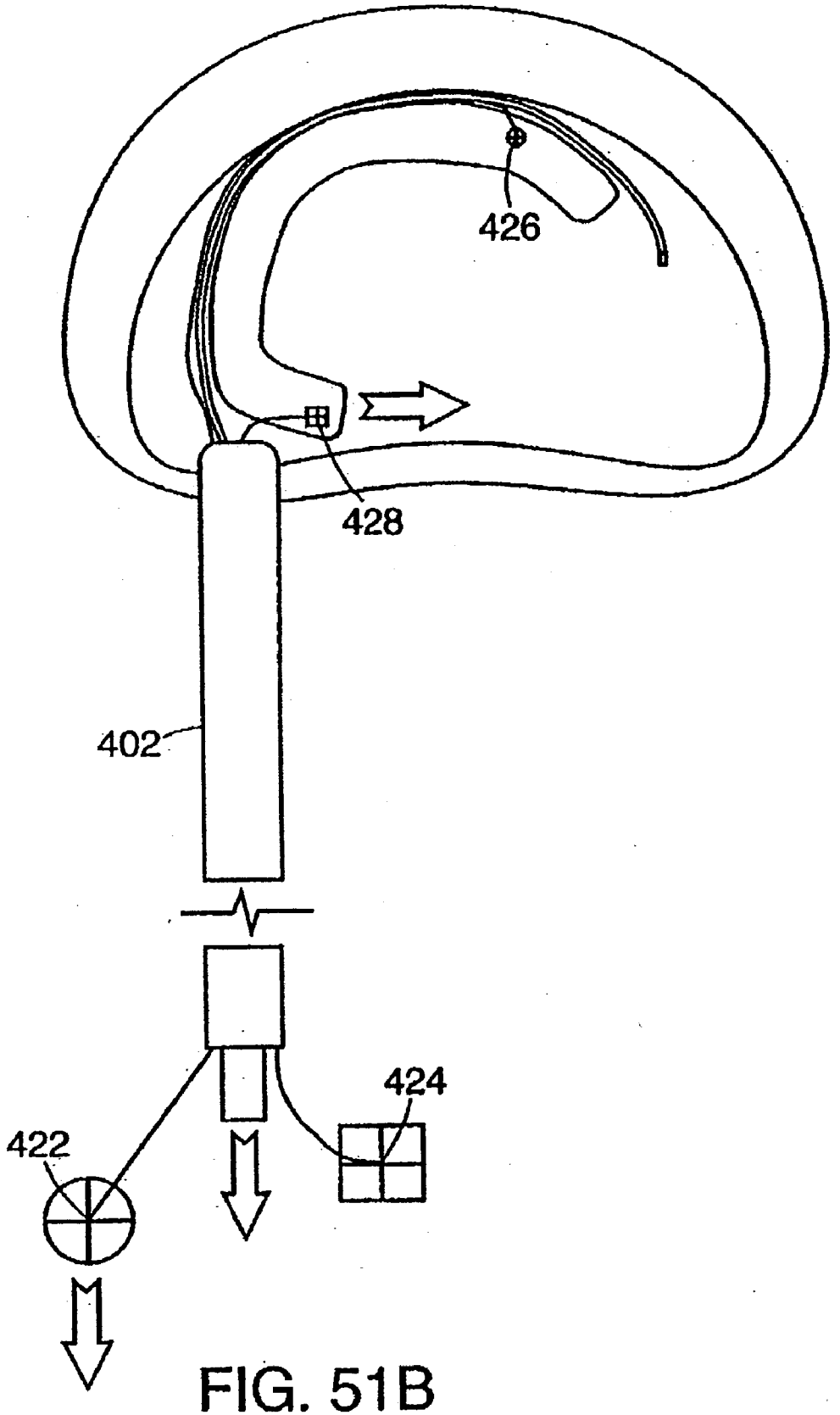


FIG. 51B

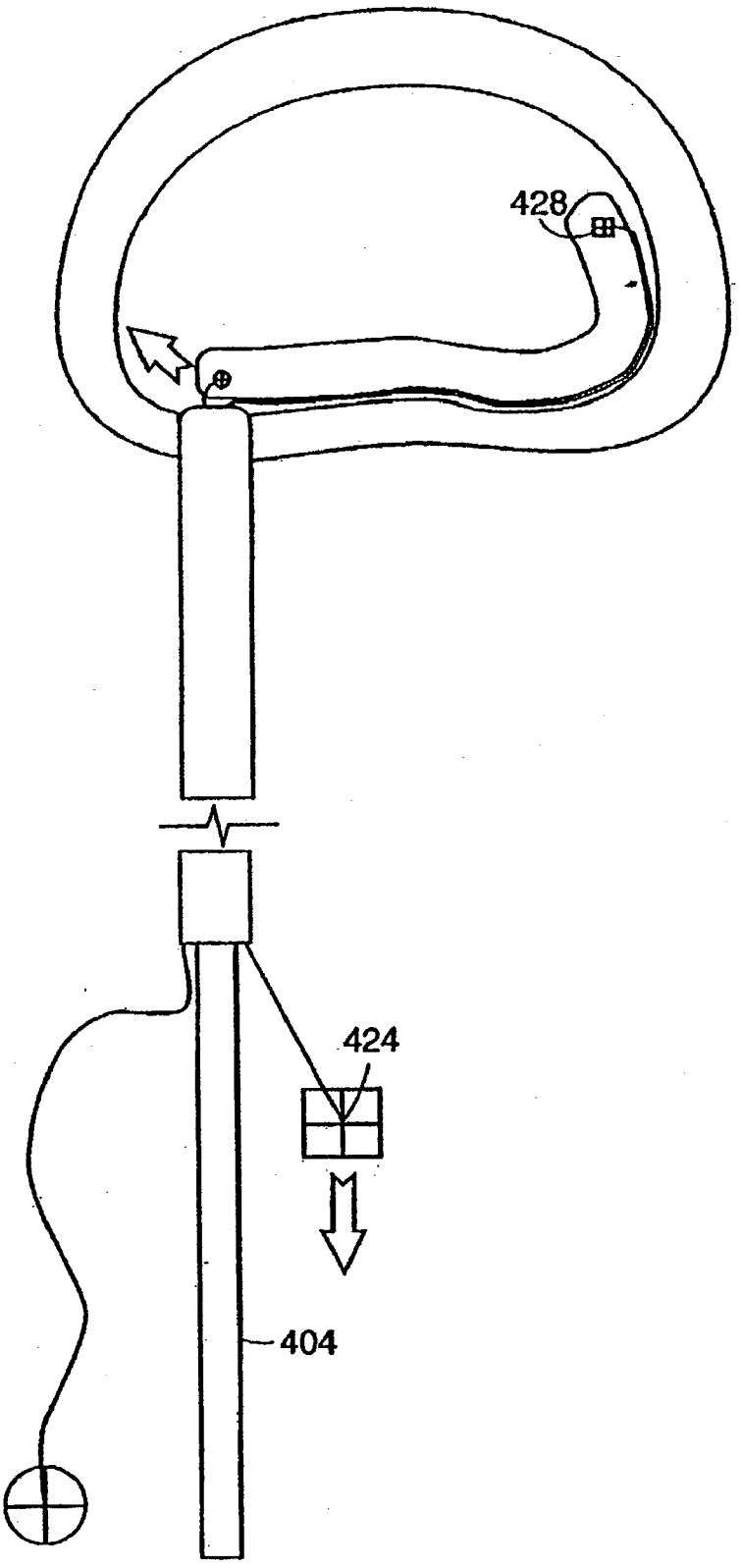


FIG. 51C

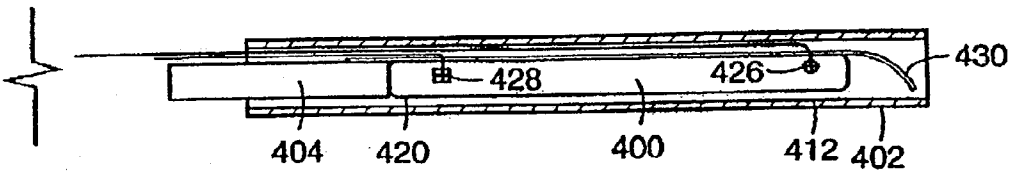


FIG. 52A

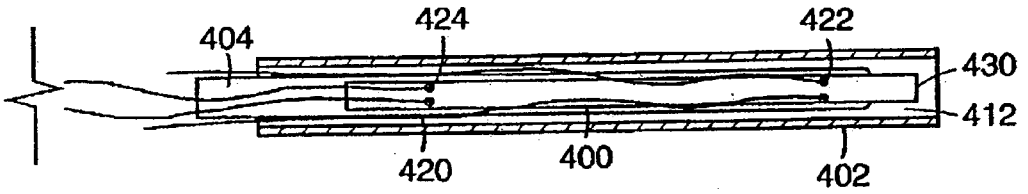


FIG. 52B

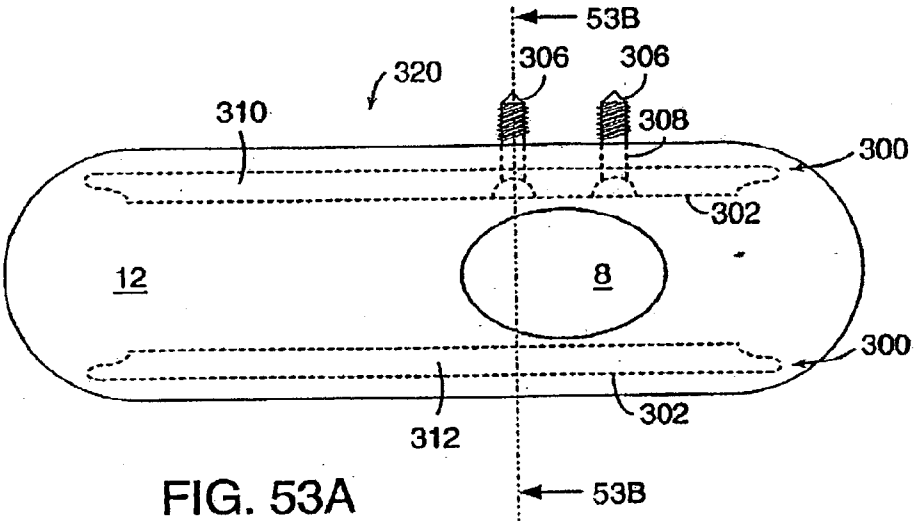


FIG. 53A

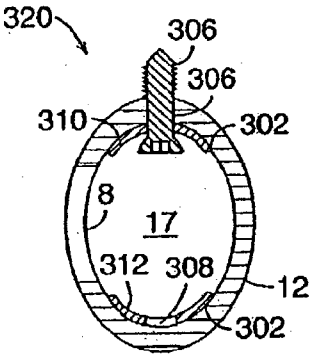


FIG. 53B

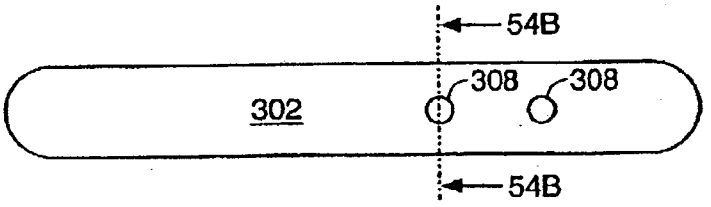


FIG. 54A

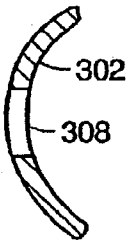


FIG. 54B

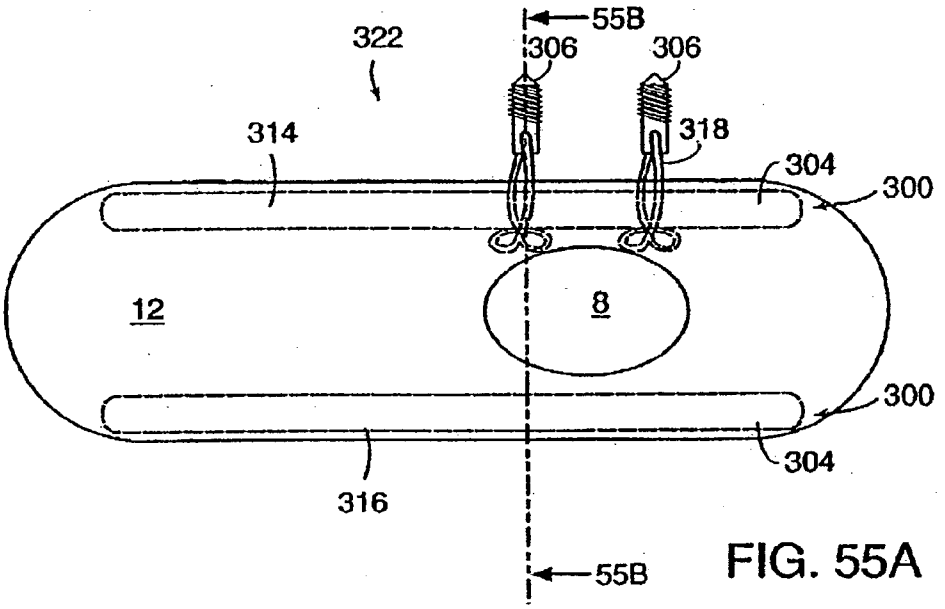


FIG. 55A

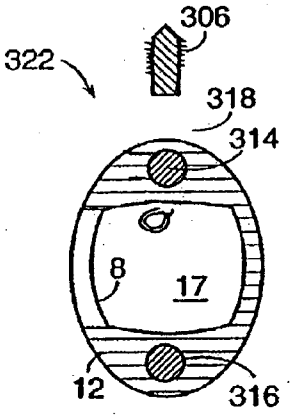


FIG. 55B

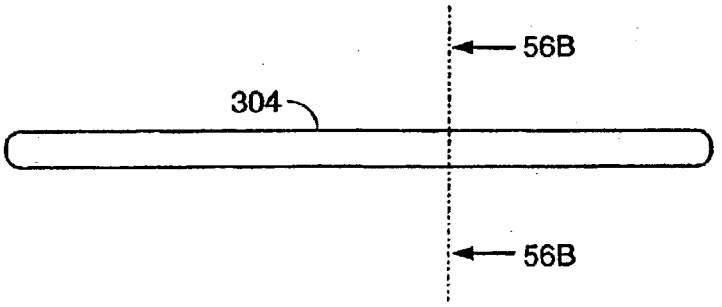


FIG. 56A

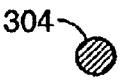


FIG. 56B

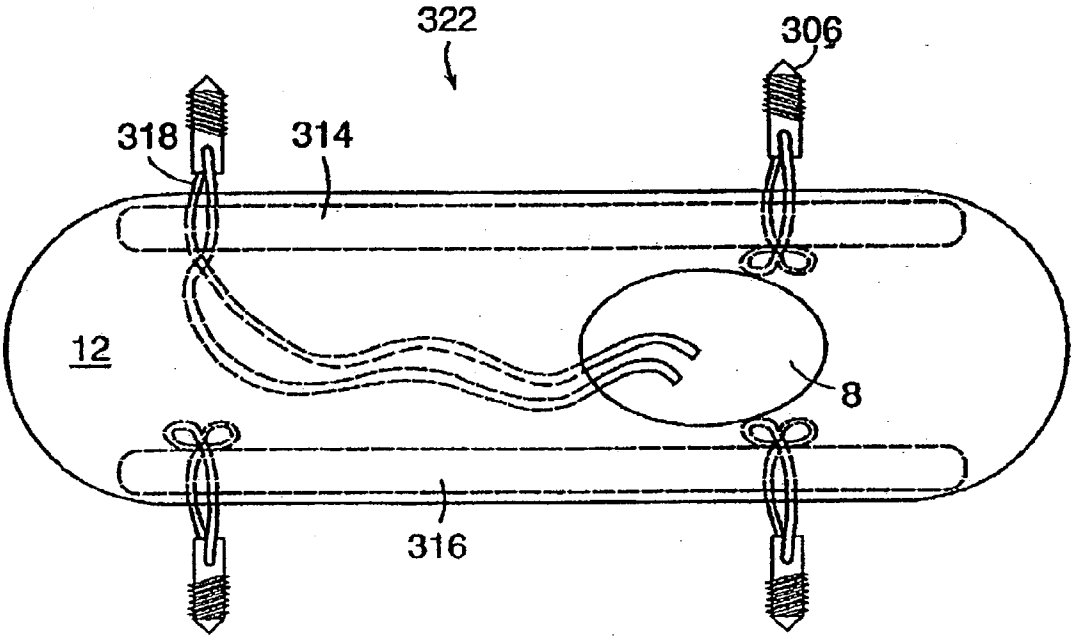


FIG. 57

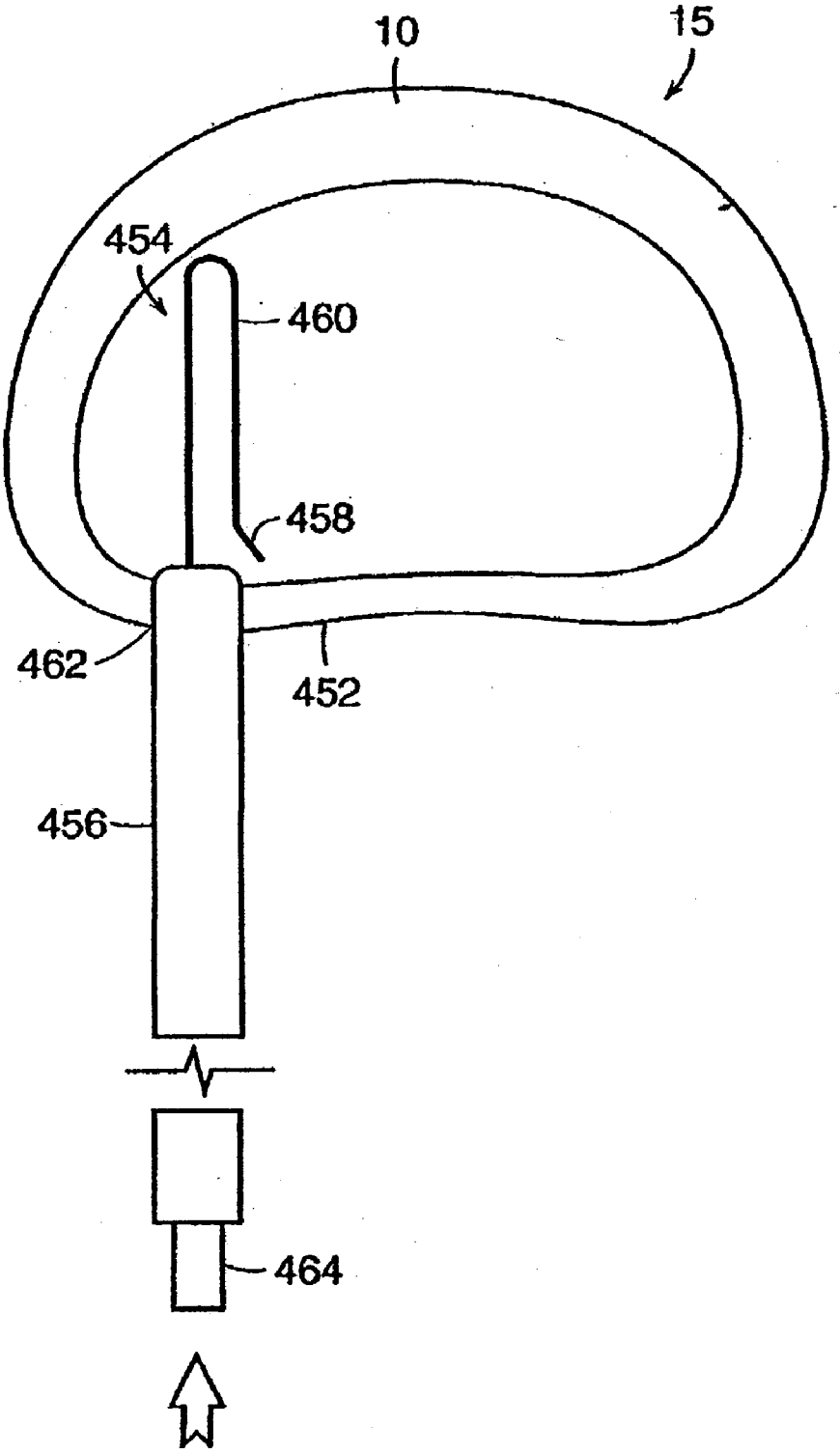


FIG. 58A

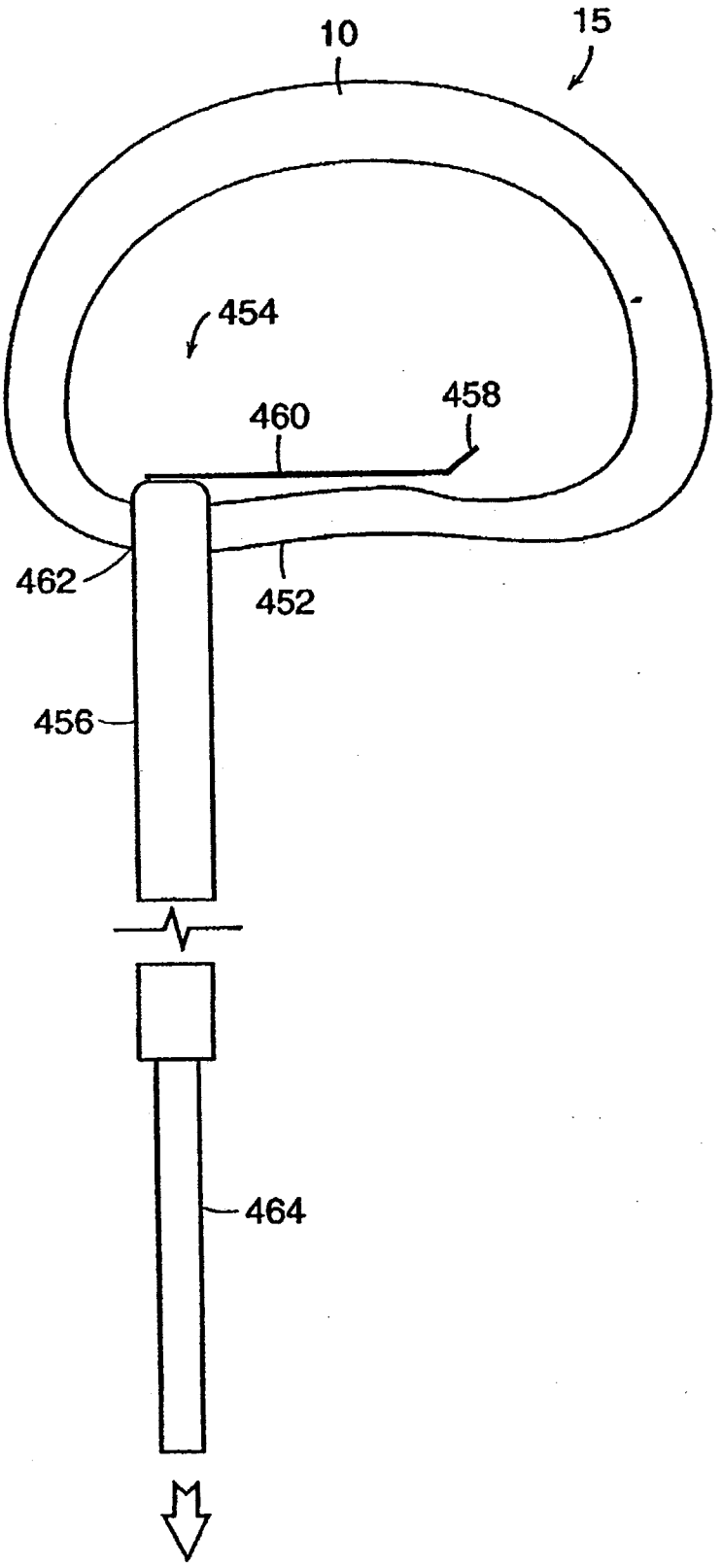


FIG. 58B

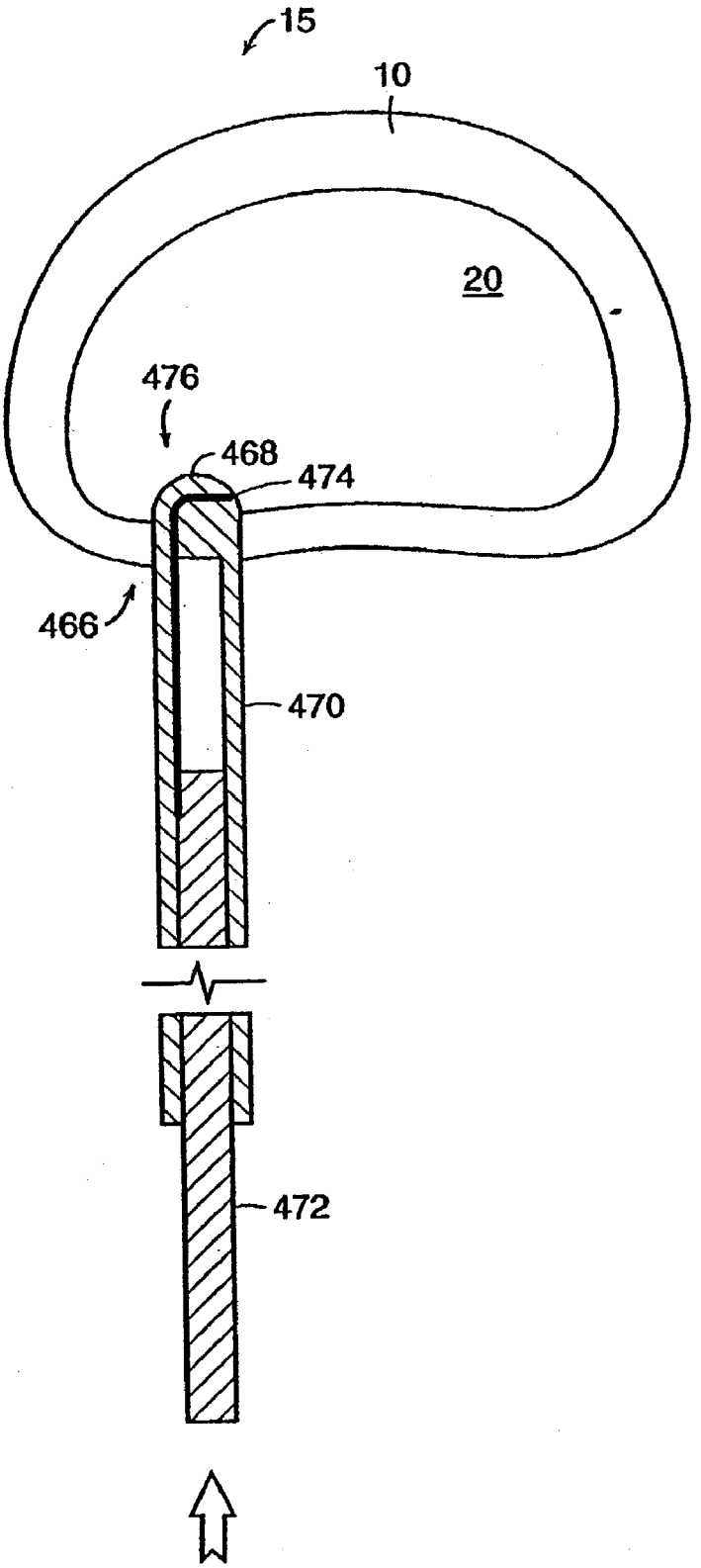


FIG. 59A

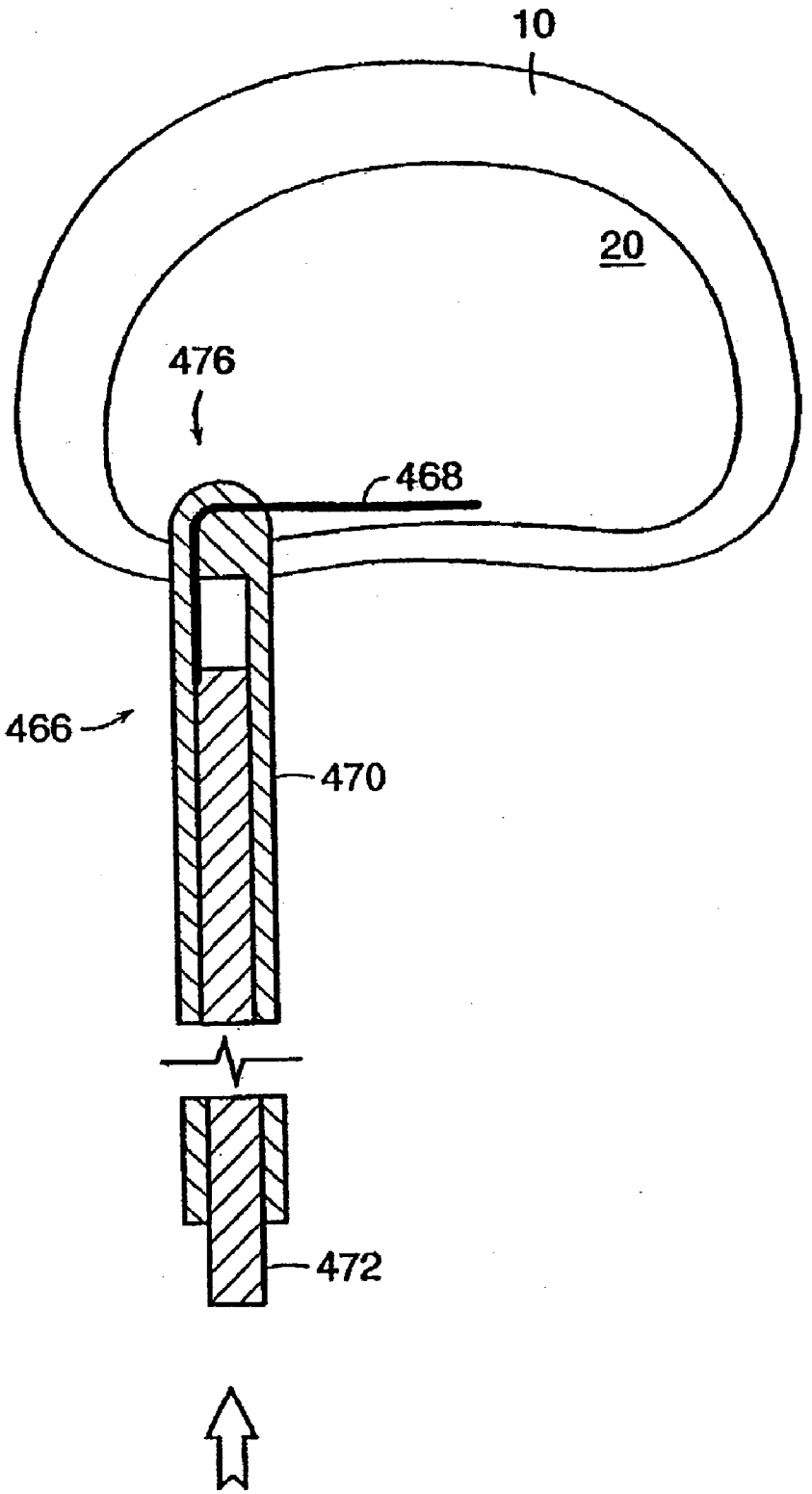


FIG. 59B

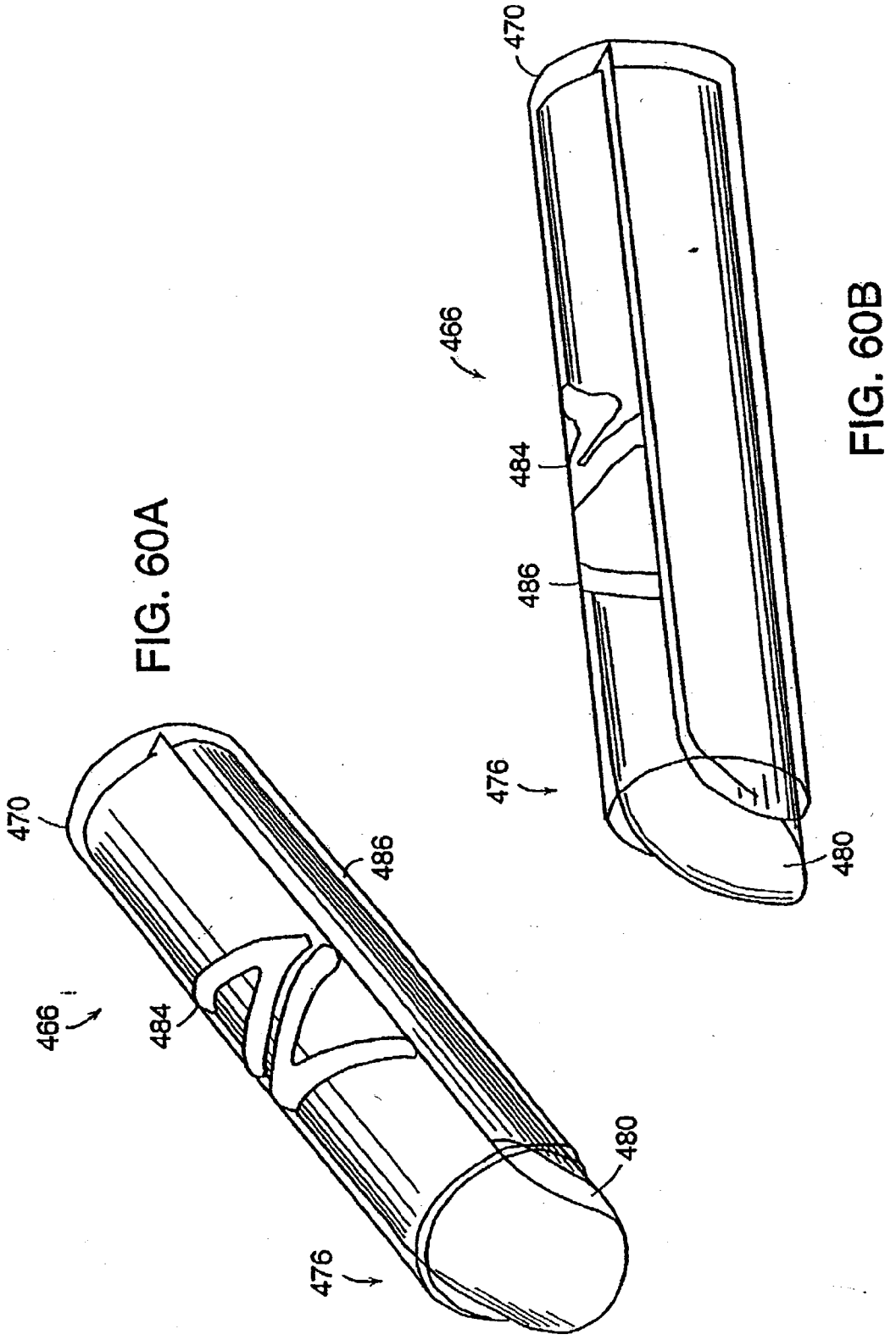


FIG. 60A

FIG. 60B

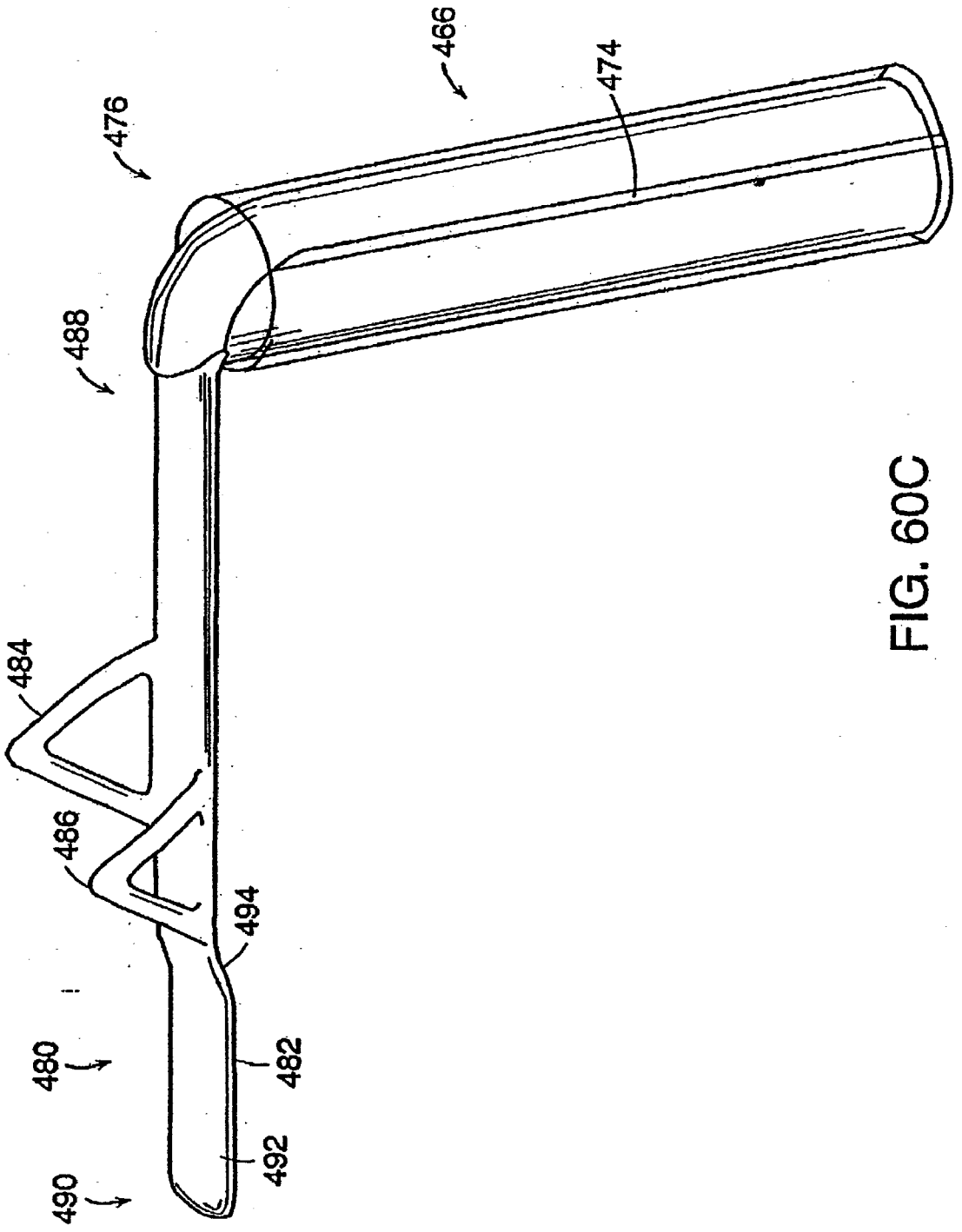


FIG. 60C

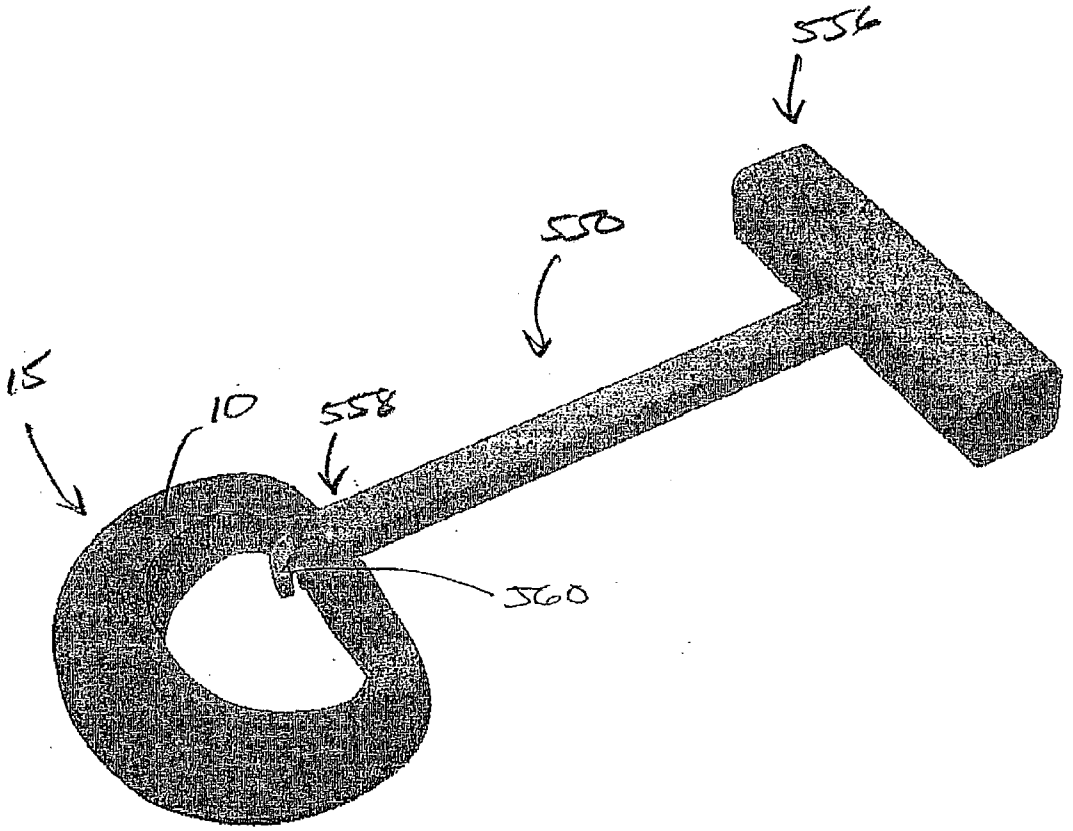


Figure 61A

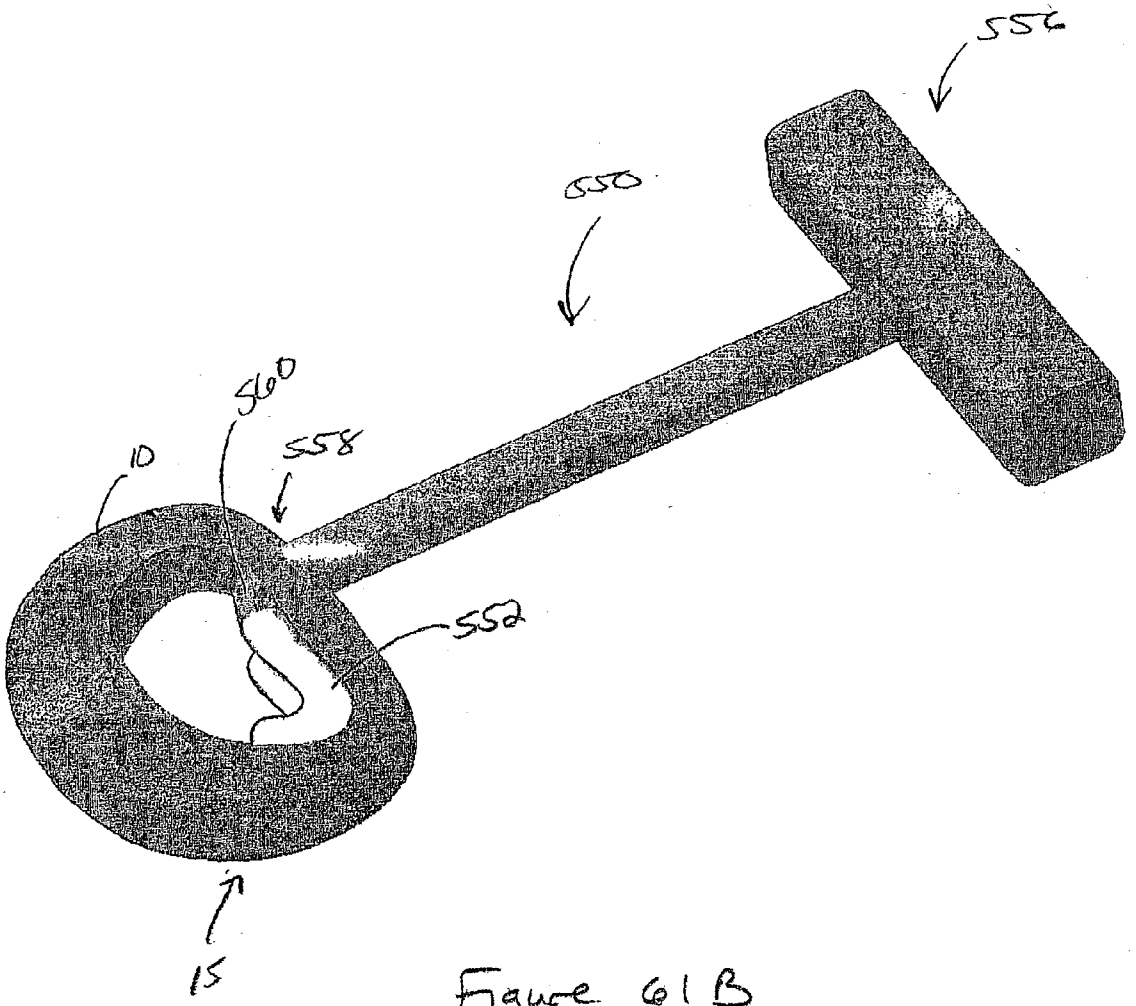


Figure 61B

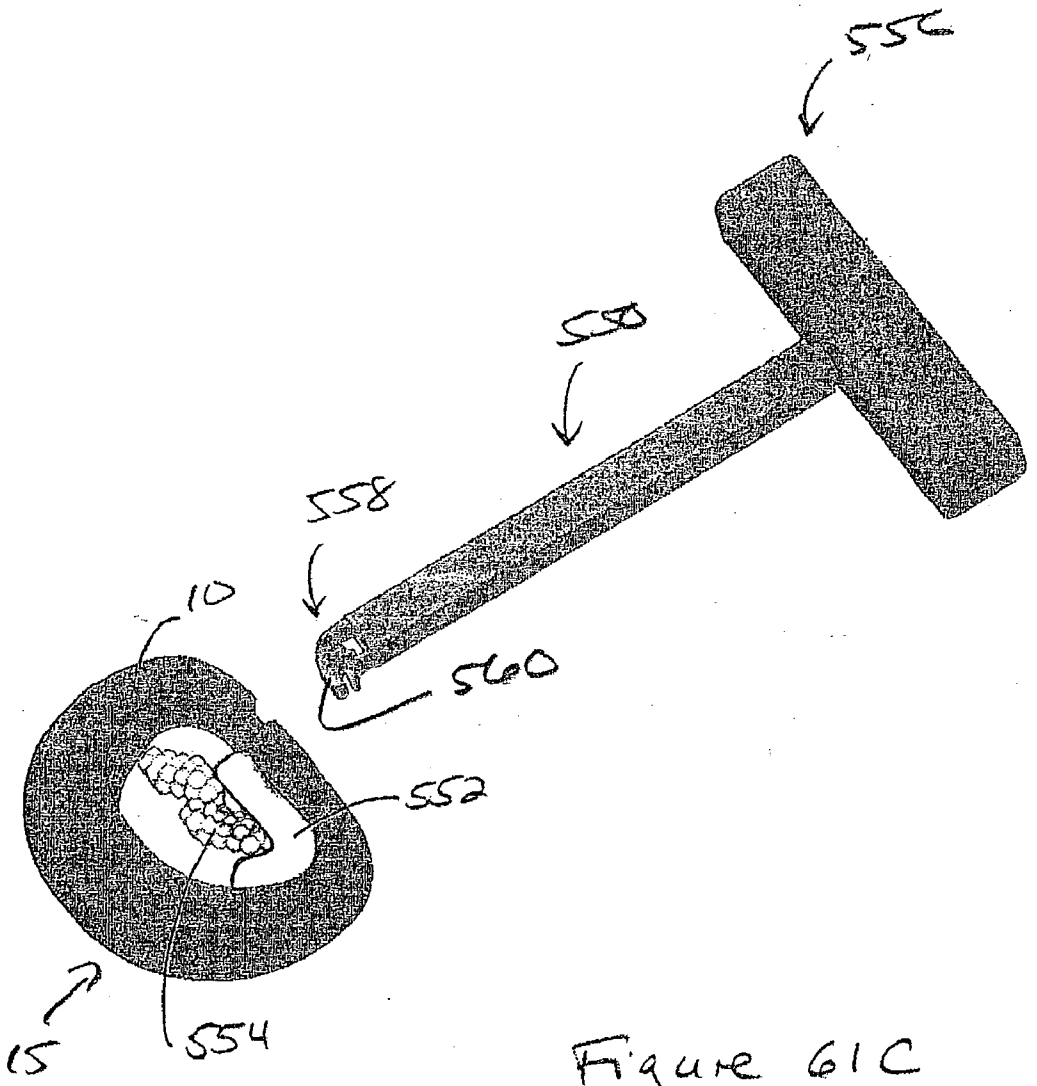


Figure 61C

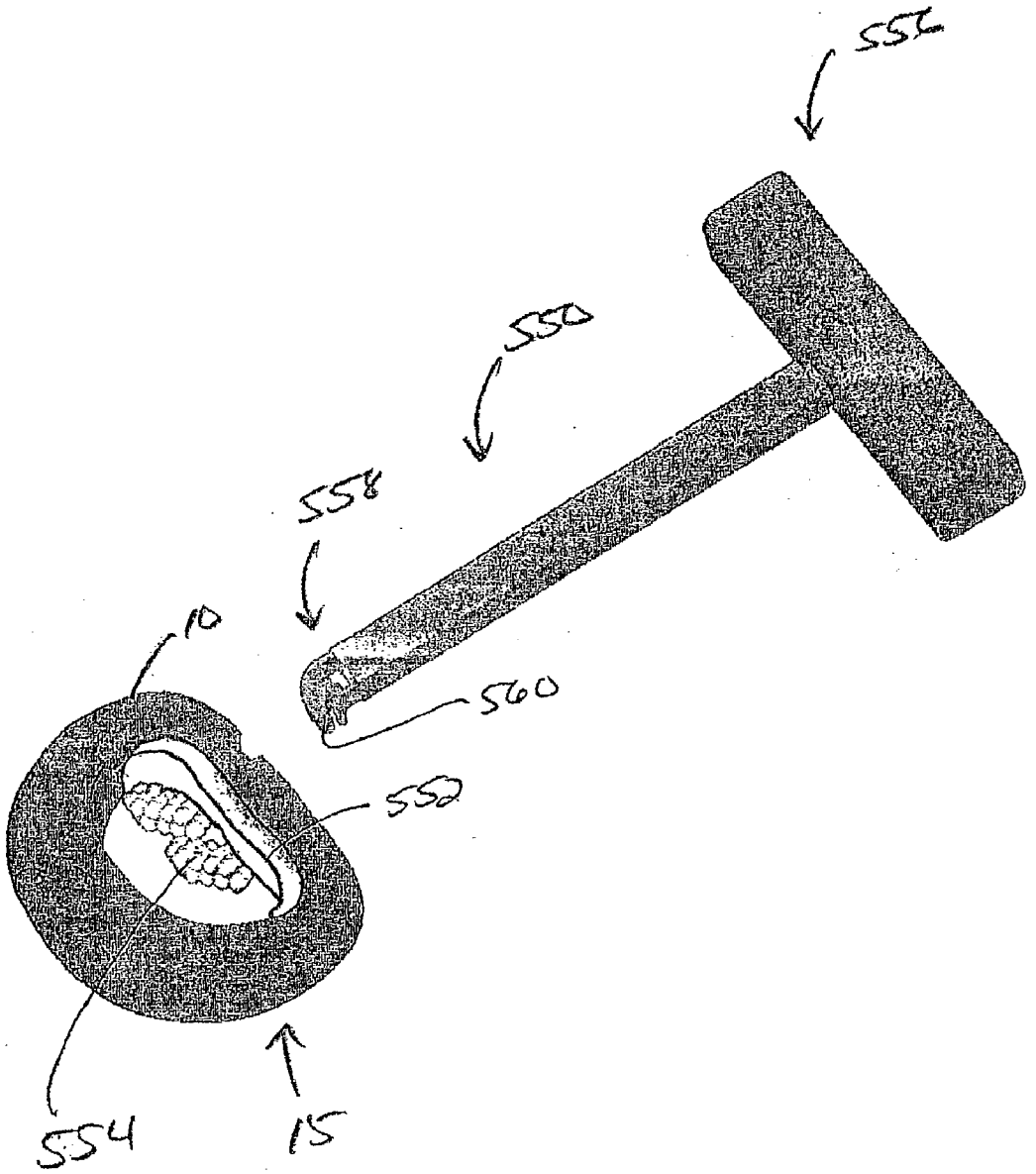


Figure 61D

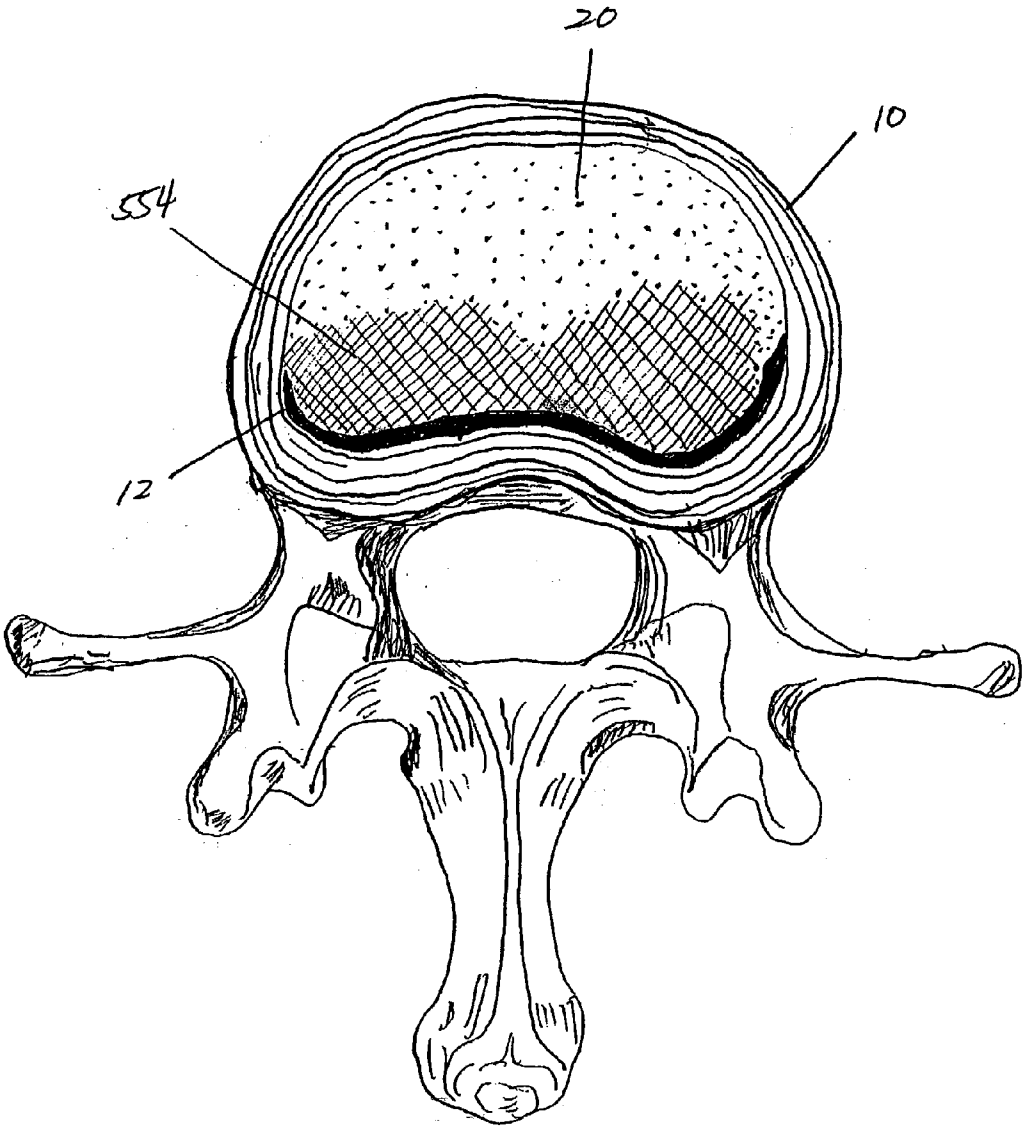


FIG. 62

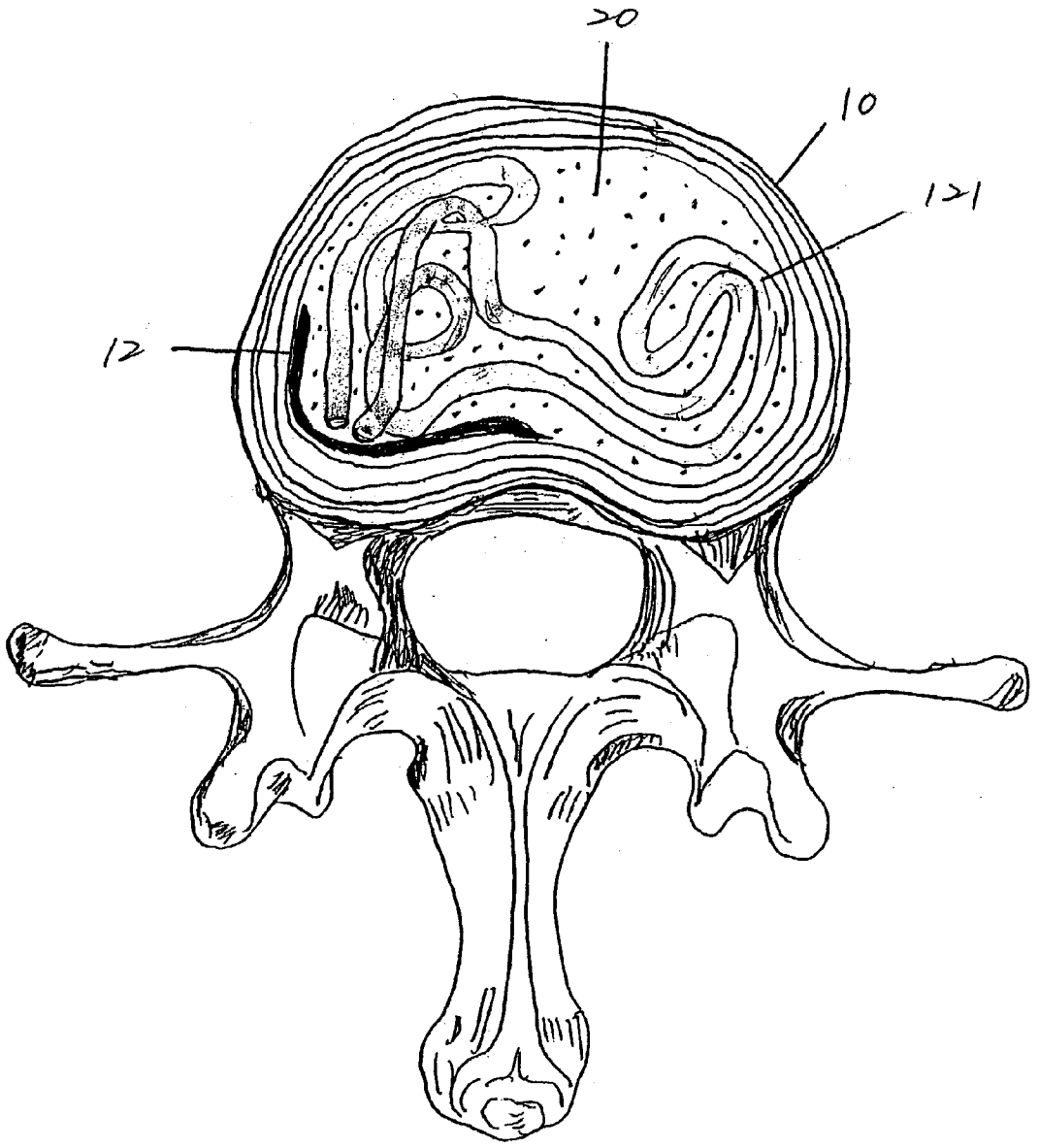


FIG. 63

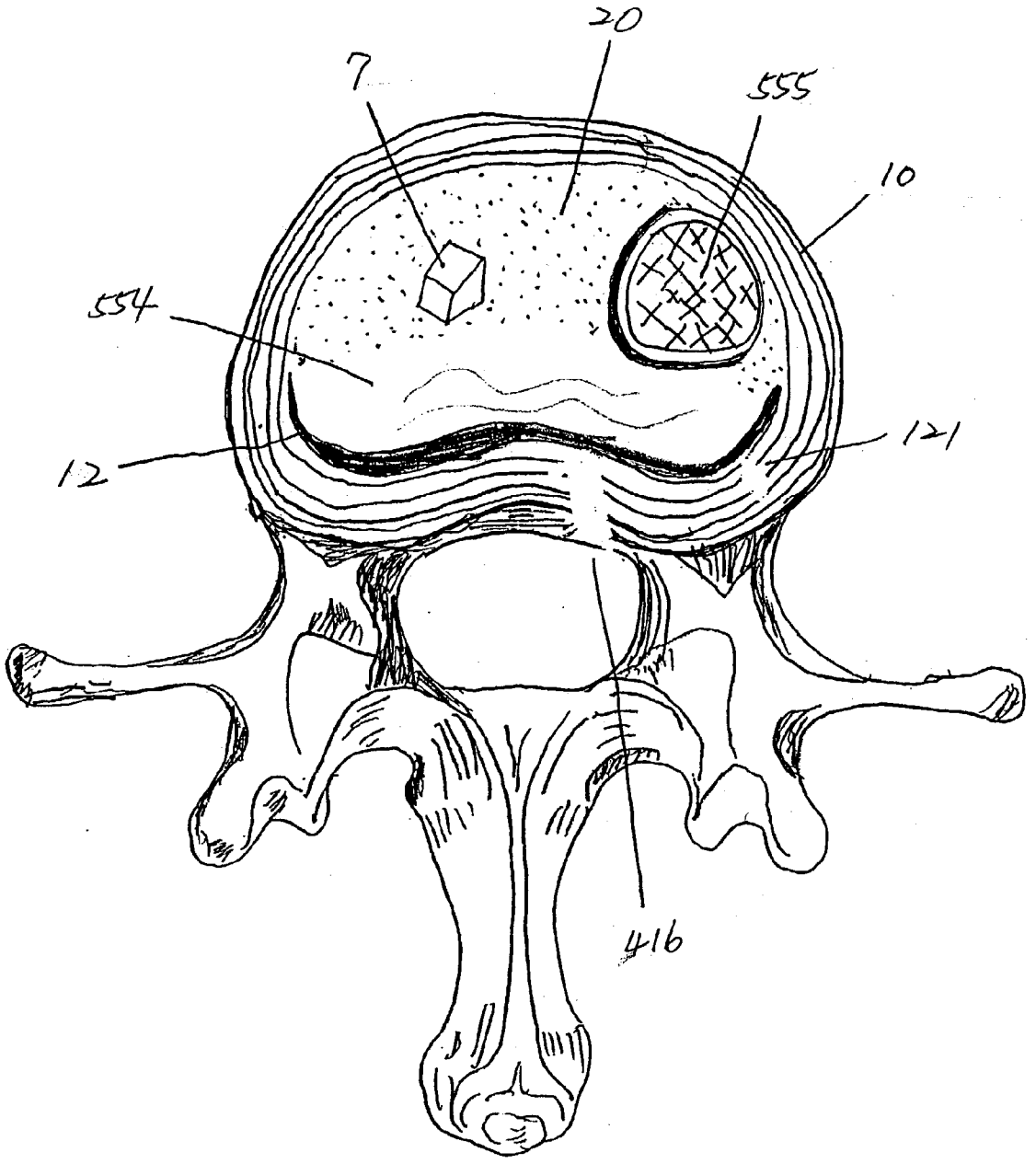


FIG. 64

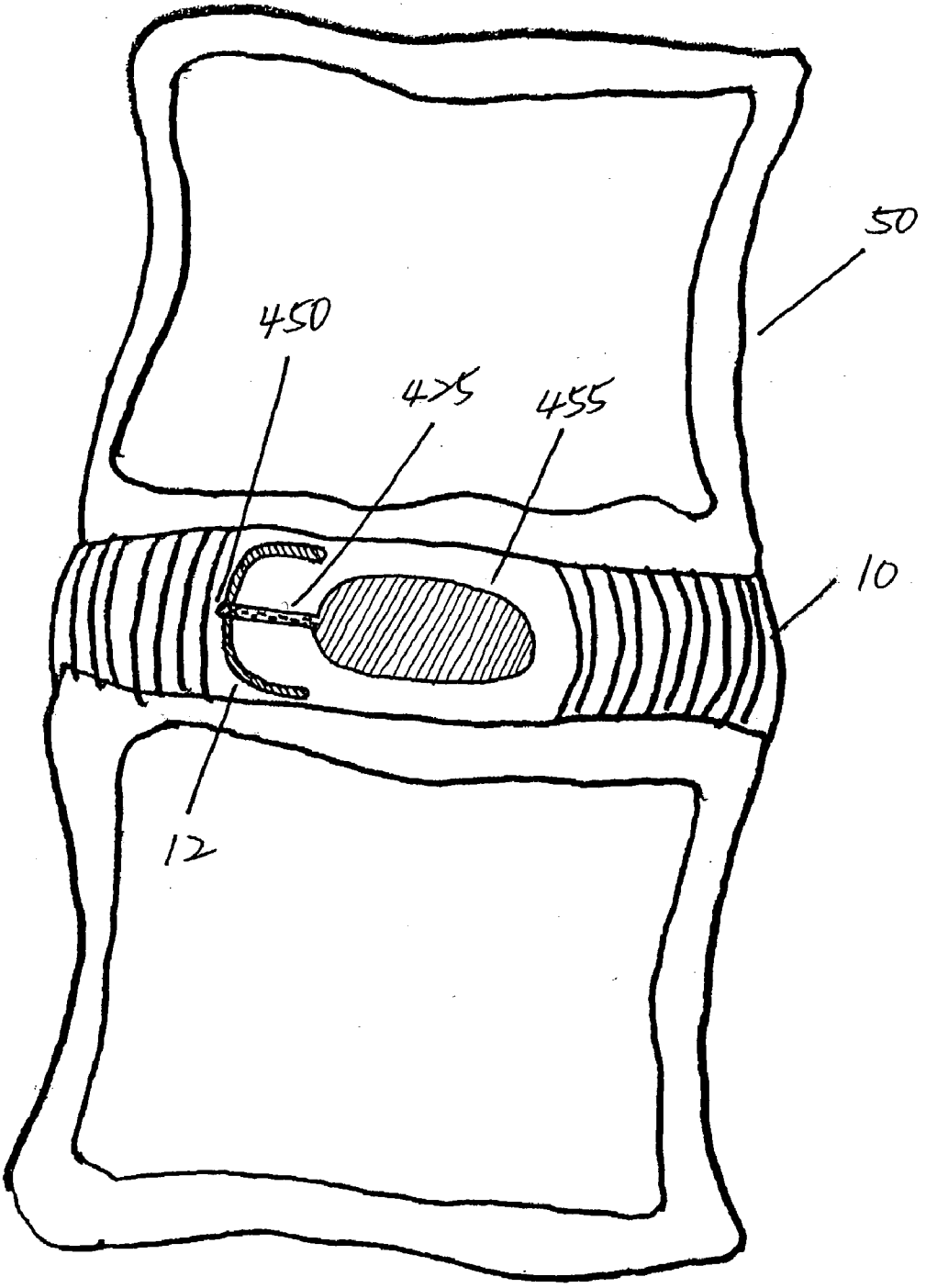


FIG. 65

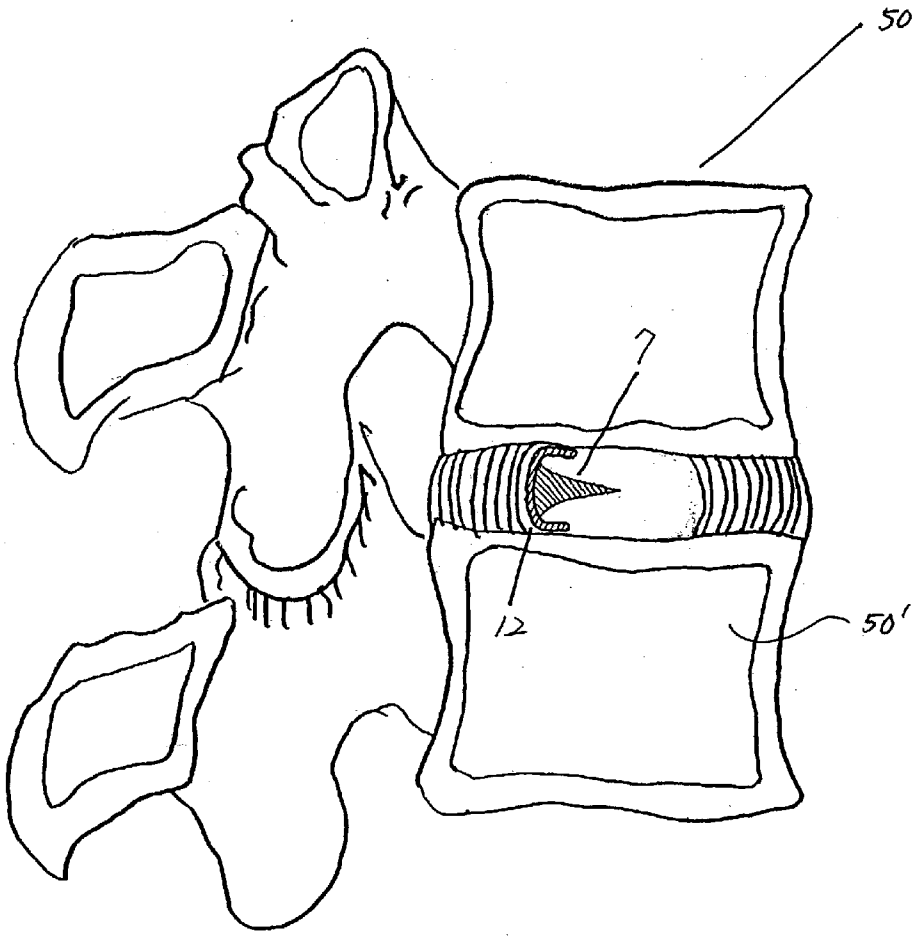


FIG. 66

METHOD OF DEFECT CLOSURE IN ANULUS FIBROSUS

RELATED APPLICATIONS

[0001] This application is a continuation of co-pending U.S. application Ser. No. 10/055,504, filed on Oct. 25, 2001, which is a continuation-in-part of U.S. application Ser. No. 09/696,636 filed on Oct. 25, 2000, now issued as U.S. Pat. No. 6,508,839, which is a continuation-in-part of U.S. application Ser. No. 09/642,450 filed on Aug. 18, 2000, now issued as U.S. Pat. No. 6,482,235, which is a continuation-in-part of U.S. application Ser. No. 09/608,797 filed on Jun. 30, 2000, now issued as U.S. Pat. No. 6,425,919, and claims benefit to U.S. Provisional Application No. 60/311,586 filed Aug. 10, 2001, U.S. Provisional Application No. 60/304,545 filed on Jul. 10, 2001, U.S. Provisional Application No. 60/172,996 filed Dec. 21, 1999, U.S. Provisional Application No. 60/161,085 filed Oct. 25, 1999, and U.S. Provisional Application No. 60/149,490 filed Aug. 18, 1999, the entire teachings of these applications being incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to the surgical treatment of intervertebral discs in the lumbar, cervical, or thoracic spine that have suffered from tears in the anulus fibrosis, herniation of the nucleus pulposus and/or significant disc height loss.

[0004] 2. Description of the Related Art

[0005] The disc performs the important role of absorbing mechanical loads while allowing for constrained flexibility of the spine. The disc is composed of a soft, central nucleus pulposus (NP) surrounded by a tough, woven anulus fibrosis (AF). Herniation is a result of a weakening in the AF. Symptomatic herniations occur when weakness in the AF allows the NP to bulge or leak posteriorly toward the spinal cord and major nerve roots. The most common resulting symptoms are pain radiating along a compressed nerve and low back pain, both of which can be crippling for the patient. The significance of this problem is increased by the low average age of diagnosis, with over 80% of patients in the U.S. being under 59.

[0006] Systems and methods for repairing tears in soft tissues are known in the art. Also, disclosed in the art are methods of augmenting the intervertebral disc. However, the efficacious treatment of intervertebral discs has not been adequately addressed using the systems and methods in the art. Accordingly, there still remains a need for devices and methods to treat intervertebral discs that have been compromised, including, but not limited to, discs that have suffered from tears in the anulus fibrosis, herniation of the nucleus pulposus and/or significant disc height loss.

SUMMARY OF THE INVENTION

[0007] Various embodiments of the present invention seek to exploit the individual characteristics of various anulus and nuclear augmentation devices to optimize the performance of both within the intervertebral disc. A primary function of anulus augmentation devices is to prevent or minimize the extrusion of materials from within the space normally occupied by the nucleus pulposus and inner anulus fibrosus. A primary function of nuclear augmentation devices is to at least temporarily add material to restore diminished disc height and pressure. Nuclear augmentation devices can also induce the growth or formation of material within the nuclear space. Accordingly, the inventive combination of these devices can create a synergistic effect wherein the anulus and nuclear augmentation devices serve to restore biomechanical function in a more natural biomimetic way. Furthermore, according to the invention both devices may be delivered more easily and less invasively. Also, the pressurized environment made possible through the addition of nuclear augmentation material and closing of the anulus serves both to restrain the nuclear augmentation and anchor the anulus augmentation in place.

[0008] One or more of the embodiments of the present invention also provide non-permanent, minimally invasive and removable devices for closing a defect in an anulus and augmenting the nucleus.

[0009] One or more of the embodiments of the present invention additionally provide an anulus augmentation device that is adapted for use with flowable nuclear augmentation material such that the flowable material cannot escape from the anulus after the anulus augmentation device has been implanted.

[0010] There is provided in accordance with one aspect of the present invention, a disc augmentation system configured to repair or rehabilitate an intervertebral disc. The system comprises at least one anulus augmentation device, and at least one nuclear augmentation material. The anulus augmentation device prevents or minimizes the extrusion of materials from within the space normally occupied by the nucleus pulposus and inner anulus fibrosus. In one application of the invention, the anulus augmentation device is configured for minimally invasive implantation and deployment. The anulus augmentation device may either be a permanent implant, or removable.

[0011] The nuclear augmentation material may restore diminished disc height and/or pressure. It may include factors for inducing the growth or formation of material within the nuclear space. It may either be permanent, removable, or absorbable.

[0012] The nuclear augmentation material may be in the form of liquids, gels, solids, or gases. It may include any/or combinations of steroids, antibiotics, tissue necrosis factors, tissue necrosis factor antagonists, analgesics, growth factors, genes, gene vectors, hyaluronic acid, noncross-linked collagen, collagen, fibren, liquid fat, oils, synthetic polymers, polyethylene glycol, liquid silicones, synthetic oils, saline and hydrogel. The hydrogel may be selected from the group consisting of acrylonitriles, acrylic acids, polyacrylimides, acrylimides, acrylimidines, polyacrylnitriles, and polyvinyl alcohols.

[0013] Solid form nuclear augmentation materials may be in the form of geometric shapes such as cubes, spheroids, disc-like components, ellipsoid, rhombohedral, cylindrical, or amorphous. The solid material may be in powder form, and may be selected from the group consisting of titanium, stainless steel, nitinol, cobalt, chrome, resorbable materials, polyurethane, polyesther, PEEK, PET, FEP, PTFE, ePTFE, PMMA, nylon, carbon fiber, Delrin, polyvinyl alcohol gels,

polyglycolic acid, polyethylene glycol, silicone gel, silicone rubber, vulcanized rubber, gas-filled vesicles, bone, hydroxy apetite, collagen such as cross-linked collagen, muscle tissue, fat, cellulose, keratin, cartilage, protein polymers, transplanted nucleus pulposus, bioengineered nucleus pulposus, transplanted anulus fibrosis, and bioengineered anulus fibrosis. Structures may also be utilized, such as inflatable balloons or other inflatable containers, and spring-biased structures.

[0014] The nuclear augmentation material may additionally comprise a biologically active compound. The compound may be selected from the group consisting of drug carriers, genetic vectors, genes, therapeutic agents, growth renewal agents, growth inhibitory agents, analgesics, anti-infectious agents, and anti-inflammatory drugs.

[0015] In accordance with another aspect of the present invention, there is provided a method of repairing or rehabilitating an intervertebral disk. The method comprises the steps of inserting at least one anulus augmentation device into the disc, and inserting at least one nuclear augmentation material, to be held within the disc by the anulus augmentation device. The nuclear augmentation material may conform to a first, healthy region of the anulus, while the anulus augmentation device conforms to a second, weaker region of the anulus.

[0016] In another aspect of the invention, a method of closing a defect in an anulus fibrosus of an intervertebral disc is provided. In one embodiment, a barrier is inserted through an opening into a disc and positioned relative to the defect such that the barrier obstructs passage of material from the interior of the disc into the defect. In one embodiment, the opening is spatially separated from said defect. In one embodiment, the opening is the defect.

[0017] In one embodiment, the barrier is larger than in area than the defect. In one aspect of the invention, the barrier is expandable. In another aspect, the barrier is expanded from a compressed state after insertion to the interior of the disc. In one embodiment, the barrier is expand within the intervertebral disc, but not inside said defect.

[0018] In one aspect of the invention, a method of repairing an annular defect in an intervertebral disc is provided. In one embodiment, a first barrier is inserted into an interior of the disc and positioned proximate to an interior aspect of the defect. A second barrier is positioned proximate to the exterior aspect of the defect and the first barrier is affixed to the second barrier using a fixation device. In one aspect, a suture and/or anchoring device is used to affix the first and second barriers.

[0019] Further features and advantages of the present invention will become apparent to those of skill in the art in view of the detailed description of preferred embodiments which follows, when taken together with the attached drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

[0021] **FIG. 1A** shows a transverse section of a portion of a functional spine unit, in which part of a vertebra and intervertebral disc are depicted.

[0022] **FIG. 1B** shows a sagittal cross section of a portion of a functional spine unit shown in **FIG. 1A**, in which two lumbar vertebrae and the intervertebral disc are visible.

[0023] **FIG. 1C** shows partial disruption of the inner layers of an anulus fibrosis.

[0024] **FIG. 2A** shows a transverse section of one aspect of the present invention prior to supporting a herniated segment.

[0025] **FIG. 2B** shows a transverse section of the construct in **FIG. 2A** supporting the herniated segment.

[0026] **FIG. 3A** shows a transverse section of another embodiment of the disclosed invention after placement of the device.

[0027] **FIG. 3B** shows a transverse section of the construct in **FIG. 3A** after tension is applied to support the herniated segment.

[0028] **FIG. 4A** shows a transverse view of an alternate embodiment of the invention.

[0029] **FIG. 4B** shows a sagittal view of the alternate embodiment shown in **FIG. 4A**.

[0030] **FIG. 5A** shows a transverse view of another aspect of the present invention.

[0031] **FIG. 5B** shows the delivery tube of **FIG. 5A** being used to displace the herniated segment to within its pre-herniated borders.

[0032] **FIG. 5C** shows a one-piece embodiment of the invention in an anchored and supporting position.

[0033] **FIG. 6** shows one embodiment of the invention supporting a weakened posterior anulus fibrosis.

[0034] **FIG. 7A** shows a transverse section of another aspect of the disclosed invention demonstrating two stages involved in augmentation of the soft tissues of the disc.

[0035] **FIG. 7B** shows a sagittal view of the invention shown in **FIG. 7A**.

[0036] **FIG. 8** shows a transverse section of one aspect of the disclosed invention involving augmentation of the soft tissues of the disc and support/closure of the anulus fibrosis.

[0037] **FIG. 9A** shows a transverse section of one aspect of the invention involving augmentation of the soft tissues of the disc with the flexible augmentation material anchored to the anterior lateral anulus fibrosis.

[0038] **FIG. 9B** shows a transverse section of one aspect of the disclosed invention involving augmentation of the soft tissues of the disc with the flexible augmentation material anchored to the anulus fibrosis by a one-piece anchor.

[0039] **FIG. 10A** shows a transverse section of one aspect of the disclosed invention involving augmentation of the soft tissues of the disc.

[0040] **FIG. 10B** shows the construct of **FIG. 10A** after the augmentation material has been inserted into the disc.

[0041] **FIG. 11** illustrates a transverse section of a barrier mounted within an anulus.

[0042] **FIG. 12** shows a sagittal view of the barrier of **FIG. 11**.

[0043] **FIG. 13** shows a transverse section of a barrier anchored within a disc.

[0044] **FIG. 14** illustrates a sagittal view of the barrier shown in **FIG. 13**.

[0045] **FIG. 15** illustrates the use of a second anchoring device for a barrier mounted within a disc.

[0046] **FIG. 16A** is an transverse view of the intervertebral disc.

[0047] **FIG. 16B** is a sagittal section along the midline of the intervertebral disc.

[0048] **FIG. 17** is an axial view of the intervertebral disc with the right half of a scaling means of a barrier means being placed against the interior aspect of a defect in anulus fibrosis by a dissection/delivery tool.

[0049] **FIG. 18** illustrates a full sealing means placed on the interior aspect of a defect in anulus fibrosis.

[0050] **FIG. 19** depicts the sealing means of **FIG. 18** being secured to tissues surrounding the defect.

[0051] **FIG. 20** depicts the sealing means of **FIG. 19** after fixation means have been passed into surrounding tissues.

[0052] **FIG. 21A** depicts an axial view of the sealing means of **FIG. 20** having enlarging means inserted into the interior cavity.

[0053] **FIG. 21B** depicts the construct of **FIG. 21** in a sagittal section.

[0054] **FIG. 22A** shows an alternative fixation scheme for the sealing means and enlarging means.

[0055] **FIG. 22B** shows the construct of **FIG. 22A** in a sagittal section with an anchor securing a fixation region of the enlarging means to a superior vertebral body in a location proximate to the defect.

[0056] **FIG. 23A** depicts an embodiment of the barrier means of the present invention being secured to an anulus using fixation means.

[0057] **FIG. 23B** depicts an embodiment of the barrier means of **FIG. 23A** secured to an anulus by two fixation darts wherein the fixation tool has been removed.

[0058] **FIGS. 24A and 24B** depict a barrier means positioned between layers of the anulus fibrosis on either side of a defect.

[0059] **FIG. 25** depicts an axial cross section of a large version of a barrier means.

[0060] **FIG. 26** depicts an axial cross section of a barrier means in position across a defect following insertion of two augmentation devices.

[0061] **FIG. 27** depicts the barrier means as part of an elongated augmentation device.

[0062] **FIG. 28A** depicts an axial section of an alternate configuration of the augmentation device of **FIG. 27**.

[0063] **FIG. 28B** depicts a sagittal section of an alternate configuration of the augmentation device of **FIG. 27**.

[0064] FIGS. **29**A-D depict deployment of a barrier from an entry site remote from the defect in the anulus fibrosis.

[0065] **FIGS. 30A, 30B**, **31**A, **31**B, **32**A, **32**B, **33**A, and **33**B depict axial and section views, respectively, of various embodiments of the barrier.

[0066] **FIG. 34A** shows a non-axisymmetric expansion means or frame.

[0067] **FIGS. 34B and 34C** illustrate perspective views of a frame mounted within an intervertebral disc.

[0068] **FIGS. 35 and 36** illustrate alternate embodiments of the expansion means shown in **FIG. 34**.

[0069] FIGS. **37**A-C illustrate a front, side, and perspective view, respectively, of an alternate embodiment of the expansion means shown in **FIG. 34**.

[0070] **FIG. 38** shows an alternate expansion means to that shown in **FIG. 37A**.

[0071] FIGS. **39**A-D illustrate a tubular expansion means having a circular cross-section.

[0072] FIGS. **40**A-D illustrate a tubular expansion means having an oval shaped cross-section.

[0073] **FIGS. 40E, 40F** and **401** illustrate a front, back and top view, respectively of the tubular expansion means of **FIG. 40A** having a sealing means covering an exterior surface of an anulus face.

[0074] **FIGS. 40G and 40H** show the tubular expansion means of **FIG. 40A** having a sealing means covering an interior surface of an anulus face.

[0075] FIGS. **41**A-D illustrate a tubular expansion means having an egg-shaped cross-section.

[0076] **FIG. 42A**-D depicts cross sections of a preferred embodiment of sealing and enlarging means.

[0077] **FIGS. 43A and 43B** depict an alternative configuration of enlarging means.

[0078] **FIGS. 44A and 44B** depict an alternative shape of the barrier means.

[0079] **FIG. 45** is a section of a device used to affix sealing means to tissues surrounding a defect.

[0080] **FIG. 46** depicts the use of a thermal device to heat and adhere sealing means to tissues surrounding a defect.

[0081] **FIG. 47** depicts an expandable thermal element that can be used to adhere sealing means to tissues surrounding a defect.

[0082] **FIG. 48** depicts an alternative embodiment to the thermal device of **FIG. 46**.

[0083] FIGS. **49**A-G illustrate a method of implanting an intradiscal implant.

[0084] FIGS. **50**A-F show an alternate method of implanting an intradiscal implant.

[0085] FIGS. 51A-C show another alternate method of implanting an intradiscal implant.

[0086] **FIGS. 52A and 52B** illustrate an implant guide used with the intradiscal implant system.

[0087] **FIG. 53A** illustrates a barrier having stiffening plate elements.

[0088] **FIG. 53B** illustrates a sectional view of the barrier of **FIG. 53A**.

[0089] **FIG. 54A** shows a stiffening plate.

[0090] **FIG. 54B** shows a sectional view of the stiffening plate of **FIG. 54A**.

[0091] **FIG. 55A** illustrates a barrier having stiffening rod elements.

[0092] **FIG. 55B** illustrates a sectional view of the barrier of **FIG. 55A**.

[0093] **FIG. 56A** illustrates a stiffening rod.

[0094] **FIG. 56B** illustrates a sectional view of the stiffening rod of **FIG. 56A**.

[0095] **FIG. 57** shows an alternate configuration for the location of the fixation devices of the barrier of **FIG. 44A**.

[0096] **FIGS. 58A and 58B** illustrate a dissection device for an intervertebral disc.

[0097] **FIGS. 59A and 59B** illustrate an alternate dissection device for an intervertebral disc.

[0098] FIGS. 60A-C illustrate a dissector component.

[0099] FIGS. 61A-D illustrate a method of inserting a disc implant within an intervertebral disc.

[0100] **FIG. 62** depicts a cross-sectional transverse view of a barrier device implanted within a disc along the inner surface of a lamella. Implanted conformable nuclear augmentation is also shown in contact with the barrier.

[0101] **FIG. 63** shows a cross-sectional transverse view of a barrier device implanted within a disc along an inner surface of a lamella. Implanted nuclear augmentation comprised of a hydrophilic flexible solid is also shown.

[0102] **FIG. 64** shows a cross-sectional transverse view of a barrier device implanted within a disc along an inner surface of a lamella. Several types of implanted nuclear augmentation including a solid geometric shape, a composite solid, and a free flowing liquid are also shown.

[0103] **FIG. 65** illustrates a sagittal cross-sectional view of a barrier device connected to an inflatable nuclear augmentation device.

[0104] **FIG. 66** depicts a sagittal cross-sectional view of a functional spine unit containing a barrier device unit connected to a wedge shaped nuclear augmentation device.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0105] The present invention provides for an in vivo augmented functional spine unit. A functional spine unit includes the bony structures of two adjacent vertebrae (or vertebral bodies), the soft tissue (anulus fibrosis (AF), and optionally nucleus pulposus (NP)) of the intervertebral disc, and the ligaments, musculature and connective tissue connected to the vertebrae. The intervertebral disc is substantially situated in the intervertebral space formed between the adjacent vertebrae. Augmentation of the functional spine unit can include repair of a herniated disc segment, support of a weakened, torn or damaged anulus fibrosis, or the addition of material to or replacement of all or part of the nucleus pulposus. Augmentation of the functional spine unit is provided by herniation constraining devices and disc augmentation devices situated in the intervertebral disc space.

[0106] **FIGS. 1A and 1B** show the general anatomy of a functional spine unit **45**. In this description and the following claims, the terms 'anterior' and 'posterior', 'superior' and 'inferior' are defined by their standard usage in anatomy, i.e., anterior is a direction toward the front (ventral) side of the body or organ, posterior is a direction toward the back (dorsal) side of the body or organ; superior is upward (toward the head) and inferior is lower (toward the feet).

[0107] **FIG. 1A** is an axial view along the transverse axis M of a vertebral body with the intervertebral disc **15** superior to the vertebral body. Axis M shows the anterior (A) and posterior (P) orientation of the functional spine unit within the anatomy. The intervertebral disc **15** contains the anulus fibrosis (AF) **10** which surrounds a central nucleus pulposus (NP) **20**. A Herniated segment **30** is depicted by a dashed-line. The herniated segment **30** protrudes beyond the pre-herniated posterior border **40** of the disc. Also shown in this figure are the left **70** and right **70'** transverse spinous processes and the posterior spinous process **80**.

[0108] **FIG. 1B** is a sagittal section along sagittal axis N through the midline of two adjacent vertebral bodies **50** (superior) and **50'** (inferior). Intervertebral disc space **55** is formed between the two vertebral bodies and contains intervertebral disc **15**, which supports and cushions the vertebral bodies and permits movement of the two vertebral bodies with respect to each other and other adjacent functional spine units.

[0109] Intervertebral disc **15** is comprised of the outer AF **10** which normally surrounds and constrains the NP **20** to be wholly within the borders of the intervertebral disc space. In **FIGS. 1A and 1B**, herniated segment **30**, represented by the dashed-line, has migrated posterior to the pre-herniated border **40** of the posterior AF of the disc. Axis M extends between the anterior (A) and posterior (P) of the functional spine unit. The vertebral bodies also include facet joints **60** and the superior **90** and inferior **90'** pedicle that form the neural foramen **100**. Disc height loss occurs when the superior vertebral body **50** moves inferiorly relative to the inferior vertebral body **50'**.

[0110] Partial disruption **121** of the inner layers of the anulus **10** without a true perforation has also been linked to chronic low back pain. Such a disruption **4** is illustrated in **FIG. 1C**. It is thought that weakness of these inner layers forces the sensitive outer anulus lamellae to endure higher stresses. This increased stress stimulates the small nerve fibers penetrating the outer anulus, which results in both localized and referred pain.

[0111] In one embodiment of the present invention, the disc herniation constraining devices **13** provide support for returning all or part of the herniated segment **30** to a position

substantially within its pre-herniated borders **40**. The disc herniation constraining device includes an anchor which is positioned at a site within the functional spine unit, such as the superior or inferior vertebral body, or the anterior medial, or anterior lateral anulus fibrosis. The anchor is used as a point against which all or part of the herniated segment is tensioned so as to return the herniated segment to its pre-herniated borders, and thereby relieve pressure on otherwise compressed neural tissue and structures. A support member is positioned in or posterior to the herniated segment, and is connected to the anchor by a connecting member. Sufficient tension is applied to the connecting member so that the support member returns the herniated segment to a pre-herniated position. In various embodiments, augmentation material is secured within the intervertebral disc space, which assists the NP in cushioning and supporting the inferior and superior vertebral bodies. An anchor secured in a portion of the functional spine unit and attached to the connection member and augmentation material limits movement of the augmentation material within the intervertebral disc space. A supporting member, located opposite the anchor, may optionally provide a second point of attachment for the connection member and further hinder the movement of the augmentation material within the intervertebral disc space.

[**0112**] **FIGS. 2A and 2B** depict one embodiment of device **13**. **FIG. 2A** shows the elements of the constraining device in position to correct the herniated segment. Anchor **1** is securely established in a location within the functional spine unit, such as the anterior AF shown in the figure. Support member **2** is positioned in or posterior to herniated segment **30**. Leading from and connected to anchor **1** is connection member **3**, which serves to connect anchor **1** to support member **2**. Depending on the location chosen for support member **2**, the connection member may traverse through all or part of the herniated segment.

[**0113**] **FIG. 2B** shows the positions of the various elements of the herniation constraining device **13** when the device **13** is supporting the herniated segment. Tightening connection member **2** allows it to transmit tensile forces along its length, which causes herniated segment **30** to move anteriorly, i.e., in the direction of its pre-herniated borders. Once herniated segment **30** is in the desired position, connection member **3** is secured in a permanent fashion between anchor **1** and support member **2**. This maintains tension between anchor **1** and support member **2** and restricts motion of the herniated segment to within the pre-herniated borders **40** of the disc. Support member **2** is used to anchor to herniated segment **30**, support a weakened AF in which no visual evidence of herniation is apparent, and may also be used to close a defect in the AF in the vicinity of herniated segment **30**.

[**0114**] Anchor **1** is depicted in a representative form, as it can take one of many suitable shapes, be made from one of a variety of biocompatible materials, and be constructed so as to fall within a range of stiffness. It can be a permanent device constructed of durable plastic or metal or can be made from a resorbable material such as polylactic acid (PLA) or polyglycolic acid (PGA). Specific embodiments are not shown, but many possible designs would be obvious to anyone skilled in the art. Embodiments include, but are not limited to, a barbed anchor made of PLA or a metal coil that can be screwed into the anterior AF. Anchor **1** can be securely established within a portion of the functional spine unit in the usual and customary manner for such devices and locations, such as being screwed into bone, sutured into tissue or bone, or affixed to tissue or bone using an adhesive method, such as cement, or other suitable surgical adhesives. Once established within the bone or tissue, anchor **1** should remain relatively stationary within the bone or tissue.

[**0115**] Support member **2** is also depicted in a representative format and shares the same flexibility in material and design as anchor **1**. Both device elements can be of the same design, or they can be of different designs, each better suited to being established in healthy and diseased tissue respectively. Alternatively, in other forms, support member **2** can be a cap or a bead shape, which also serves to secure a tear or puncture in the AF, or it can be bar or plate shaped, with or without barbs to maintain secure contact with the herniated segment. Support member **2** can be established securely to, within, or posterior to the herniated segment.

[**0116**] The anchor and support member can include suture, bone anchors, soft tissue anchors, tissue adhesives, and materials that support tissue ingrowth although other forms and materials are possible. They may be permanent devices or resorbable. Their attachment to a portion of FSU and herniated segment must be strong enough to resist the tensional forces that result from repair of the hernia and the loads generated during daily activities.

[**0117**] Connection member **3** is also depicted in representative fashion. Member **3** may be in the format of a flexible filament, such as a single or multi-strand suture, wire, or perhaps a rigid rod or broad band of material, for example. The connection member can further include suture, wire, pins, and woven tubes or webs of material. It can be constructed from a variety of materials, either permanent or resorbable, and can be of any shape suitable to fit within the confines of the intervertebral disc space. The material chosen is preferably adapted to be relatively stiff while in tension, and relatively flexible against all other loads. This allows for maximal mobility of the herniated segment relative to the anchor without the risk of the supported segment moving outside of the pre-herniated borders of the disc. The connection member may be an integral component of either the anchor or support member or a separate component. For example, the connection member and support member could be a length of non-resorbing suture that is coupled to an anchor, tensioned against the anchor, and sewn to the herniated segment.

[**0118**] **FIGS. 3A and 3B** depict another embodiment of device **13**. In **FIG. 3A** the elements of the herniation constraining device are shown in position prior to securing a herniated segment. Anchor **1** is positioned in the AF and connection member **3** is attached to anchor **1**. Support member **4** is positioned posterior to the posterior-most aspect of herniated segment **30**. In this way, support member **4** does not need to be secured in herniated segment **30** to cause herniated segment **30** to move within the pre-herniated borders **40** of the disc. Support member **4** has the same flexibility in design and material as anchor **1**, and may further take the form of a flexible patch or rigid plate or bar of material that is either affixed to the posterior aspect of herniated segment **30** or is simply in a form that is larger than any hole in the AF directly anterior to support member **4**. **FIG. 3B** shows the positions of the elements of the device

when tension is applied between anchor **1** and support member **4** along connection member **3**. The herniated segment is displaced anteriorly, within the pre-herniated borders **40** of the disc.

[**0119**] **FIGS. 4A and 4B** show five examples of suitable anchoring sites within the FSU for anchor **1**. **FIG. 4A** shows an axial view of anchor **1** in various positions within the anterior and lateral AF. **FIG. 4B** similarly shows a sagittal view of the various acceptable anchoring sites for anchor **1**. Anchor **1** is secured in the superior vertebral body **50**, inferior vertebral body **50'** or anterior AF **10**, although any site that can withstand the tension between anchor **1** and support member **2** along connection member **3** to support a herniated segment within its pre-herniated borders **40** is acceptable.

[**0120**] Generally, a suitable position for affixing one or more anchors is a location anterior to the herniated segment such that, when tension is applied along connection member **3**, herniated segment **30** is returned to a site within the pre-herniated borders **40**. The site chosen for the anchor should be able to withstand the tensile forces applied to the anchor when the connection member is brought under tension. Because most symptomatic herniations occur in the posterior or posterior lateral directions, the preferable site for anchor placement is anterior to the site of the herniation. Any portion of the involved FSU is generally acceptable, however the anterior, anterior medial, or anterior lateral AF is preferable. These portions of the AF have been shown to have considerably greater strength and stiffness than the posterior or posterior lateral portions of the AF. As shown in **FIGS. 4A and 4B**, anchor **1** can be a single anchor in any of the shown locations, or there can be multiple anchors **1** affixed in various locations and connected to a support member **2** to support the herniated segment. Connection member **3** can be one continuous length that is threaded through the sited anchors and the support member, or it can be several individual strands of material each terminated under tension between one or more anchors and one or more support members.

[**0121**] In various forms of the invention, the anchor(s) and connection member(s) may be introduced and implanted in the patient, with the connection member under tension. Alternatively, those elements may be installed, without introducing tension to the connection member, but where the connection member is adapted to be under tension when the patient is in a non-horizontal position, i.e., resulting from loading in the intervertebral disc.

[**0122**] FIGS. **5**A-C show an alternate embodiment of herniation constraining device **13**A. In this series of figures, device **13**A, a substantially one-piece construct, is delivered through a delivery tube **6**, although device **13**A could be delivered in a variety of ways including, but not limited to, by hand or by a hand held grasping instrument. In **FIG. 5A**, device **13**A in delivery tube **6** is positioned against herniated segment **30**. In **FIG. 5B**, the herniated segment is displaced within its pre-herniated borders **40** by device **13**A and/or delivery tube **6** such that when, in **FIG. 5C**, device **13**A has been delivered through delivery tube **6**, and secured within a portion of the FSU, the device supports the displaced herniated segment within its pre-herniated border **40**. Herniation constraining device **13**A can be made of a variety of materials and have one of many possible forms so long as it allows support of the herniated segment **30** within the pre-herniated borders **40** of the disc. Device **13**A can anchor the herniated segment **30** to any suitable anchoring site within the FSU, including, but not limited to the superior vertebral body, inferior vertebral body, or anterior AF. Device **13**A may be used additionally to close a defect in the AF of herniated segment **30**. Alternatively, any such defect may be left open or may be closed using another means.

[**0123**] **FIG. 6** depicts the substantially one-piece device **13**A supporting a weakened segment **30'** of the posterior AF **10'**. Device **13**A is positioned in or posterior to the weakened segment **30'** and secured to a portion of the FSU, such as the superior vertebral body **50**, shown in the figure, or the inferior vertebral body **50'** or anterior or anterior-lateral anulus fibrosis **10**. In certain patients, there may be no obvious herniation found at surgery. However, a weakened or torn AF that may not be protruding beyond the pre-herniated borders of the disc may still induce the surgeon to remove all or part of the NP in order to decrease the risk of herniation. As an alternative to discectomy, any of the embodiments of the invention may be used to support and perhaps close defects in weakened segments of AF.

[**0124**] A further embodiment of the present invention involves augmentation of the soft tissues of the intervertebral disc to avoid or reverse disc height loss. **FIGS. 7A and 7B** show one embodiment of device **13** securing augmentation material in the intervertebral disc space **55**. In the left side of **FIG. 7A**, anchors **1** have been established in the anterior AF **10**. Augmentation material **7** is in the process of being inserted into the disc space along connection member **3** which, in this embodiment, has passageway **9**. Support member **2'** is shown ready to be attached to connection member **3** once the augmentation material **7** is properly situated. In this embodiment, connection member **3** passes through an aperture **11** in support member **2'**, although many other methods of affixing support member **2'** to connection member **3** are possible and within the scope of this invention.

[**0125**] Augmentation material **7** may have a passageway **9**, such as a channel, slit or the like, which allows it to slide along the connection member **3**, or augmentation material **7** may be solid, and connection member **3** can be threaded through augmentation material by means such as needle or other puncturing device. Connection member **3** is affixed at one end to anchor **1** and terminated at its other end by a support member **2'**, one embodiment of which is shown in the figure in a cap-like configuration. Support member **2'** can be affixed to connection member **3** in a variety of ways, including, but not limited to, swaging support member **2'** to connection member **3**. In a preferred embodiment, support member **2'** is in a cap configuration and has a dimension (diameter or length and width) larger than the optional passageway **9**, which serves to prevent augmentation material **7** from displacing posteriorly with respect to anchor **1**. The right half of the intervertebral disc of **FIG. 7A** (axial view) and **FIG. 7B** (sagittal view) show augmentation material **7** that has been implanted into the disc space **55** along connection member **3** where it supports the vertebral bodies **50** and **50'**. **FIG. 7A** shows an embodiment in which support member **2'** is affixed to connection member **3** and serves only to prevent augmentation material **7** from moving off connection member **3**. The augmentation device is free to move within the disc space. **FIG. 7B** shows an alternate

embodiment in which support member **2'** is embedded in a site in the functional spine unit, such as a herniated segment or posterior anulus fibrosis, to further restrict the movement of augmentation material **7** or spacer material within the disc space.

[**0126**] Augmentation or spacer material can be made of any biocompatible, preferably flexible, material. Such a flexible material is preferably fibrous, like cellulose or bovine or autologous collagen. The augmentation material can be plug or disc shaped. It can further be cube-like, ellipsoid, spheroid or any other suitable shape. The augmentation material can be secured within the intervertebral space by a variety of methods, such as but not limited to, a suture loop attached to, around, or through the material, which is then passed to the anchor and support member.

[**0127**] **FIGS. 8, 9A**, 9B and **10A** and **10B** depict further embodiments of the disc herniation constraining device **13**B in use for augmenting soft tissue, particularly tissue within the intervertebral space. In the embodiments shown in **FIGS. 8 and 9**A, device **13**B is secured within the intervertebral disc space providing additional support for NP **20**. Anchor **1** is securely affixed in a portion of the FSU, (anterior AF **10** in these figures). Connection member **3** terminates at support member **2**, preventing augmentation material **7** from migrating generally posteriorly with respect to anchor **1**. Support member **2** is depicted in these figures as established in various locations, such as the posterior AF **10'** in **FIG. 8**, but support member **2** may be anchored in any suitable location within the FSU, as described previously. Support member **2** may be used to close a defect in the posterior AF. It may also be used to displace a herniated segment to within the pre-herniated borders of the disc by applying tension between anchoring means **1** and **2** along connection member **3**.

[**0128**] **FIG. 9A** depicts anchor **1**, connection member **3**, spacer material **7** and support member **2'** (shown in the "cap"-type configuration) inserted as a single construct and anchored to a site within the disc space, such as the inferior or superior vertebral bodies. This configuration simplifies insertion of the embodiments depicted in **FIGS. 7 and 8** by reducing the number of steps to achieve implantation. Connection member **3** is preferably relatively stiff in tension, but flexible against all other loads. Support member **2'** is depicted as a bar element that is larger than passageway **9** in at least one plane.

[**0129**] **FIG. 9B** depicts a variation on the embodiment depicted in **FIG. 9A**. **FIG. 9B** shows substantially one-piece disc augmentation device **13**C, secured in the intervertebral disc space. Device **13**C has anchor **1**, connection member **3** and augmentation material **7**. Augmentation material **7** and anchor **1** could be pre-assembled prior to insertion into the disc space **55** as a single construct. Alternatively, augmentation material **7** could be inserted first into the disc space and then anchored to a portion of the FSU by anchor **1**.

[**0130**] **FIGS. 10A and 10B** show yet another embodiment of the disclosed invention, **13**D. In **FIG. 10A**, two connection members **3** and **3'** are attached to anchor **1**. Two plugs of augmentation material **7** and **7'** are inserted into the disc space along connection members **3** and **3'**. Connection members **3** and **3'** are then bound together (e.g., knotted together, fused, or the like). This forms loop **3"** that serves to prevent augmentation materials **7** and **7'** from displacing posteriorly. **FIG. 10B** shows the position of the augmentation material **7** after it is secured by the loop **3"** and anchor **1**. Various combinations of augmentation material, connecting members and anchors can be used in this embodiment, such as using a single plug of augmentation material, or two connection members leading from anchor **1** with each of the connection members being bound to at least one other connection member. It could further be accomplished with more than one anchor with at least one connection member leading from each anchor, and each of the connection members being bound to at least one other connection member.

[**0131**] Any of the devices described herein can be used for closing defects in the AF whether created surgically or during the herniation event. Such methods may also involve the addition of biocompatible material to either the AF or NP. This material could include sequestered or extruded segments of the NP found outside the pre-herniated borders of the disc.

[**0132**] **FIGS. 11-15** illustrate devices used in and methods for closing a defect in an anulus fibrosis. One method involves the insertion of a barrier or barrier means **12** into the disc **15**. This procedure can accompany surgical discectomy. It can also be done without the removal of any portion of the disc **15** and further in combination with the insertion of an augmentation material or device into the disc **15**.

[**0133**] The method consists of inserting the barrier **12** into the interior of the disc **15** and positioning it proximate to the interior aspect of the anulus defect **16**. The barrier material is preferably considerably larger in area than the size of the defect **16**, such that at least some portion of the barrier means **12** abuts healthier anulus fibrosis **10**. The device acts to seal the anulus defect **16**, recreating the closed isobaric environment of a healthy disc nucleus **20**. This closure can be achieved simply by an over-sizing of the implant relative to the defect **16**. It can also be achieved by affixing the barrier means **12** to tissues within the functional spinal unit. In a preferred aspect of the present invention, the barrier **12** is affixed to the anulus surrounding the anulus defect **16**. This can be achieved with sutures, staples, glues or other suitable fixation means or fixation device **14**. The barrier means **12** can also be larger in area than the defect **16** and be affixed to a tissue or structure opposite the defect **16**, i.e. anterior tissue in the case of a posterior defect.

[**0134**] The barrier means **12** is preferably flexible in nature. It can be constructed of a woven material such as Dacron™ or Nylon™, a synthetic polyamide or polyester, a polyethylene, and can further be an expanded material, such as expanded polytetrafluroethylene (e-PTFE), for example. The barrier means **12** can also be a biologic material such as cross-linked collagen or cellulous.

[**0135**] The barrier means **12** can be a single piece of material. It can have an expandable means or component that allows it to be expanded from a compressed state after insertion into the interior of the disc **15**. This expandable means can be active, such as a balloon, or passive, such as a hydrophilic material. The expandable means can also be a self-ically expanding elastically deforming material, for example.

[**0136**] **FIGS. 11 and 12** illustrate a barrier **12** mounted within an anulus **10** and covering an anulus defect **16**. The

barrier **12** can be secured to the anulus **10** with a fixation mechanism or fixation means **14**. The fixation means **14** can include a plurality of suture loops placed through the barrier **12** and the anulus **10**. Such fixation can prevent motion or slipping of the barrier **12** away from the anulus defect **16**.

[**0137**] The barrier means **12** can also be anchored to the disc **15** in multiple locations. In one preferred embodiment, shown in **FIGS. 13 and 14**, the barrier means **12** can be affixed to the anulus tissue **10** in or surrounding the defect and further affixed to a secondary fixation site opposite the defect, e.g. the anterior anulus **10** in a posterior herniation, or the inferior **50'** or superior **50** vertebral body. For example, fixation means **14** can be used to attach the barrier **12** to the anulus **10** near the defect **16**, while an anchoring mechanism **18** can secure the barrier **12** to a secondary fixation site. A connector **22** can attach the barrier **12** to the anchor **18**. Tension can be applied between the primary and secondary fixation sites through a connector **22** so as to move the anulus defect **16** toward the secondary fixation site. This may be particularly beneficial in closing defects **16** that result in posterior herniations. By using this technique, the herniation can be moved and supported away from any posterior neural structures while further closing any defect in the anulus **10**.

[**0138**] The barrier means **12** can further be integral to a fixation means such that the barrier means affixes itself to tissues within the functional spinal unit.

[**0139**] Any of the methods described above can be augmented by the use of a second barrier or a second barrier means **24** placed proximate to the outer aspect of the defect **16** as shown in **FIG. 15**. The second barrier **24** can further be affixed to the inner barrier means **12** by the use of a fixation means **14** such as suture material.

[**0140**] **FIGS. 16A and 16B** depict intervertebral disc **15** comprising nucleus pulposus **20** and anulus fibrosis **10**. Nucleus pulposus **20** forms a first anatomic region and extra-discal space **500** (any space exterior to the disc) forms a second anatomic region wherein these regions are separated by anulus fibrosis **10**.

[**0141**] **FIG. 16A** is an axial (transverse) view of the intervertebral disc. A posterior lateral defect **16** in anulus fibrosis **10** has allowed a segment **30** of nucleus pulposus **20** to herniate into an extra discal space **500**. Interior aspect **32** and exterior aspect **34** are shown, as are the right **70'** and left **70** transverse processes and posterior process **80**.

[**0142**] **FIG. 16B** is a sagittal section along the midline intervertebral disc. Superior pedicle **90** and inferior pedicle **90'** extend posteriorly from superior vertebral body **95** and inferior vertebral body **95'** respectively.

[**0143**] To prevent further herniation of the nucleus **20** and to repair any present herniation, in a preferred embodiment, a barrier or barrier means **12** can be placed into a space between the anulus **10** and the nucleus **20** proximate to the inner aspect **32** of defect **16**, as depicted in **FIGS. 17 and 18**. The space can be created by blunt dissection. Dissection can be achieved with a separate dissection instrument, with the barrier means **12** itself, or a combined dissection/barrier delivery tool **100**. This space is preferably no larger than the barrier means such that the barrier means **12** can be in contact with both anulus **10** and nucleus **20**. This allows the barrier means **12** to transfer load from the nucleus **20** to the anulus **10** when the disc is pressurized during activity.

[**0144**] In position, the barrier means **12** preferably spans the defect **16** and extends along the interior aspect **36** of the anulus **10** until it contacts healthy tissues on all sides of the defect **16**, or on a sufficient extent of adjacent healthy tissue to provide adequate support under load. Healthy tissue may be non-diseased tissue and/or load bearing tissue, which may be micro-perforated or non-perforated. Depending on the extent of the defect **16**, the contacted tissues can include the anulus **10**, cartilage overlying the vertebral endplates, and/or the endplates themselves.

[**0145**] In the preferred embodiment, the barrier means **12** comprises two components—a sealing means or sealing component **51** and an enlarging means or enlarging component **53**, shown in **FIGS. 21A and 21B**.

[**0146**] The sealing means **51** forms the periphery of the barrier **12** and has an interior cavity **17**. There is at least one opening **8** leading into cavity **17** from the exterior of the sealing means **51**. Sealing means **51** is preferably compressible or collapsible to a dimension that can readily be inserted into the disc **15** through a relatively small hole. This hole can be the defect **16** itself or a site remote from the defect **16**. The sealing means **51** is constructed from a material and is formed in such a manner as to resist the passage of fluids and other materials around sealing means **51** and through the defect **16**. The sealing means **51** can be constructed from one or any number of a variety of materials including, but not limited to PTFE, e-PTFE, Nylon™, Marlex™, high-density polyethylene, and/or collagen. The thickness of the sealing component has been found to be optimal between about 0.001 inches (0.127 mm) and 0.063 inches (1.6 mm).

[**0147**] The enlarging means **53** can be sized to fit within cavity **17** of sealing means **51**. It is preferably a single object of a dimension that can be inserted through the same defect **16** through which the sealing means **51** was passed. The enlarging means **53** can expand the sealing means **51** to an expanded state as it is passed into cavity **17**. One purpose of enlarging means **53** is to expand sealing means **51** to a size greater than that of the defect **16** such that the assembled barrier **12** prevents passage of material through the defect **16**. The enlarger **53** can further impart stiffness to the barrier **12** such that the barrier **12** resists the pressures within nucleus pulposus **20** and expulsion through the defect **16**. The enlarging means **53** can be constructed from one or any number of materials including, but not limited to, silicon rubber, various plastics, stainless steel, nickel titanium alloys, or other metals. These materials may form a solid object, a hollow object, coiled springs or other suitable forms capable of filling cavity **17** within sealing means **51**.

[**0148**] The sealing means **51**, enlarging means **53**, or the barrier means **12** constructs can further be affixed to tissues either surrounding the defect **16** or remote from the defect **16**. In the preferred embodiment, no aspect of a fixation means or fixation device or the barrier means **12** nor its components extend posterior to the disc **15** or into the extradiscal region **500**, avoiding the risk of contacting and irritating the sensitive nerve tissues posterior to the disc **15**.

[**0149**] In a preferred embodiment, the sealing means **51** is inserted into the disc **15** proximate the interior aspect **36** of the defect. The sealing means **51** is then affixed to the tissues

surrounding the defect using a suitable fixation means, such as suture or a soft-tissue anchor. The fixation procedure is preferably performed from the interior of the sealing means cavity **17** as depicted in **FIGS. 19 and 20**. A fixation delivery instrument **110** is delivered into cavity **17** through opening **8** in the sealing means **51**. Fixation devices **14** can then be deployed through a wall of the sealing means **53** into surrounding tissues. Once the fixation means **14** have been passed into surrounding tissue, the fixation delivery instrument **110** can be removed from the disc **15**. This method eliminates the need for a separate entryway into the disc **15** for delivery of fixation means **14**. It further minimizes the risk of material leaking through sealing means **51** proximate to the fixation means **14**. One or more fixation means **14** can be delivered into one or any number of surrounding tissues including the superior **95** and inferior **95'** vertebral bodies. Following fixation of the sealing means **51**, the enlarging means **53** can be inserted into cavity **17** of the sealing means **51** to further expand the barrier means **12** construct as well as increase its stiffness, as depicted in **FIGS. 21A and 21B**. The opening **8** into the sealing means **51** can then be closed by a suture or other means, although this is not a requirement of the present invention. In certain cases, insertion of a separate enlarging means may not be necessary if adequate fixation of the sealing means **51** is achieved.

[**0150**] Another method of securing the barrier **12** to tissues is to affix the enlarging means **53** to tissues either surrounding or remote from the defect **16**. The enlarging means **53** can have an integral fixation region **4** that facilitates securing it to tissues as depicted in **FIGS. 22A, 22B, 32**A and **43**B. This fixation region **4** can extend exterior to sealing means **51** either through opening **8** or through a separate opening. Fixation region **4** can have a hole through which a fixation means or fixation device **14** can be passed. In a preferred embodiment, the barrier **12** is affixed to at least one of the surrounding vertebral bodies (**95** and **95'**) proximate to the defect using a bone anchor **14'**. The bone anchor **14'** can be deployed into the vertebral bodies **50, 50'** at some angle between 0E and 180E relative to a bone anchor deployment tool. As shown the bone anchor **14'** is mounted at 90E relative to the bone anchor deployment tool. Alternatively, the enlarging means **53** itself can have an intergral fixation device **14** located at a site or sites along its length.

[**0151**] Another method of securing the barrier means **12** is to insert the barrier means **12** through the defect **16** or another opening into the disc **15**, position it proximate to the interior aspect **36** of the defect **16**, and pass at least one fixation means **14** through the anulus **10** and into the barrier **12**. In a preferred embodiment of this method, the fixation means **14** can be darts **15** and are first passed partially into anulus **10** within a fixation device **120**, such as a hollow needle. As depicted in **FIGS. 23A and 23B**, fixation means **25** can be advanced into the barrier means **12** and fixation device **120** removed. Fixation means **25** preferably have two ends, each with a means to prevent movement of that end of the fixation device. Using this method, the fixation means can be lodged in both the barrier **12** and anulus fibrosis **10** without any aspect of fixation means **25** exterior to the disc in the extradiscal region **500**.

[**0152**] In another aspect of the present invention, the barrier (or "patch") **12** can be placed between two neighboring layers **33, 37** (lamellae) of the anulus **10** on either or both sides of the defect **16** as depicted in **FIGS. 24A and 24B**. **FIG. 24A** shows an axial view while **24**B shows a sagittal cross section. Such positioning spans the defect **16**. The barrier means **12** can be secured using the methods outlined.

[**0153**] A dissecting tool can be used to form an opening extending circumferentially **31** within the anulus fibrosis such that the barrier can be inserted into the opening. Alternatively, the barrier itself can have a dissecting edge such that it can be driven at least partially into the sidewalls of defect **16**, annulotomy **416**, access hole **417** or opening in the anulus. This process can make use of the naturally layered structure in the anulus in which adjacent layers **33, 37** are defined by a circumferentially extending boundary **35** between the layers.

[**0154**] Another embodiment of the barrier **12** is a patch having a length, oriented along the circumference of the disc, which is substantially greater than its height, which is oriented along the distance separating the surrounding vertebral bodies. A barrier **12** having a length greater than its height is illustrated in **FIG. 25**. The barrier **12** can be positioned across the defect **16** as well as the entirety of the posterior aspect of the anulus fibrosis **10**. Such dimensions of the barrier **12** can help to prevent the barrier **12** from slipping after insertion and can aid in distributing the pressure of the nucleus **20** evenly along the posterior aspect of the anulus **10**.

[**0155**] The barrier **12** can be used in conjunction with an augmentation device **11** inserted within the anulus **10**. The augmentation device **11** can include separate augmentation devices **42** as shown in **FIG. 26**. The augmentation device **11** can also be a single augmentation device **44** and can form part of the barrier **12** as barrier region **300**, coiled within the anulus fibrosis **10**, as shown in **FIG. 27**. Either the barrier **12** or barrier region **300** can be secured to the tissues surrounding the defect **16** by fixation devices or darts **25**, or be left unconstrained

[**0156**] In another embodiment of the present invention, the barrier or patch **12** may be used as part of a method to augment the intervertebral disc. In one aspect of this method, augmentation material or devices are inserted into the disc through a defect (either naturally occurring or surgically generated). Many suitable augmentation materials and devices are discussed above and in the prior art. As depicted in **FIG. 26**, the barrier means is then inserted to aid in closing the defect and/or to aid in transferring load from the augmentation materials/devices to healthy tissues surrounding the defect. In another aspect of this method, the barrier means is an integral component to an augmentation device. As shown in **FIGS. 27, 28A** and **28**B, the augmentation portion may comprise a length of elastic material that can be inserted linearly through a defect in the anulus. A region **300** of the length forms the barrier means of the present invention and can be positioned proximate to the interior aspect of the defect once the nuclear space is adequately filled. Barrier region **300** may then be affixed to surrounding tissues such as the AF and/or the neighboring vertebral bodies using any of the methods and devices described above.

[**0157**] **FIGS. 28A and 28B** illustrate axial and sagittal sections, respectively, of an alternate configuration of an augmentation device **38**. In this embodiment, barrier region

300 extends across the defect **16** and has fixation region **4** facilitating fixation of the device **13** to superior vertebral body **50** with anchor **14'**.

[**0158**] FIGS. **29**A-D illustrate the deployment of a barrier **12** from an entry site **800** remote from the defect in the anulus fibrosis **10**. **FIG. 29A** shows insertion instrument **130** with a distal end positioned within the disc space occupied by nucleus pulposus **20**. **FIG. 29B** depicts delivery catheter **140** exiting the distal end of insertion instrument **130** with barrier **12** on its distal end. Barrier **12** is positioned across the interior aspect of the defect **16**. **FIG. 29C** depicts the use of an expandable barrier **12'** wherein delivery catheter **140** is used to expand the barrier **12'** with balloon **150** on its distal end. Balloon **150** may exploit heat to further adhere barrier **12'** to surrounding tissue. **FIG. 29D** depicts removal of balloon **150** and delivery catheter **140** from the disc space leaving expanded barrier means **12'** positioned across defect **16**.

[**0159**] Another method of securing the barrier means **12** is to adhere it to surrounding tissues through the application of heat. In this embodiment, the barrier means **12** includes a sealing means **51** comprised of a thermally adherent material that adheres to surrounding tissues upon the application of heat. The thermally adherent material can include thermoplastic, collagen, or a similar material. The sealing means **51** can further comprise a separate structural material that adds strength to the thermally adherent material, such as a woven Nylon™ or Marlex™. This thermally adherent sealing means preferably has an interior cavity **17** and at least one opening **8** leading from the exterior of the barrier means into cavity **17**. A thermal device can be attached to the insertion instrument shown in **FIGS. 29C and 29D**. The insertion instrument **130** having a thermal device can be inserted into cavity **17** and used to heat sealing means **51** and surrounding tissues. This device can be a simple thermal element, such as a resistive heating coil, rod or wire. It can further be a number of electrodes capable of heating the barrier means and surrounding tissue through the application of radio frequency (RF) energy. The thermal device can further be a balloon **150**, **150'**, as shown in **FIG. 47**, capable of both heating and expanding the barrier means. Balloon **150**, **150'** can either be inflated with a heated fluid or have electrodes located about its surface to heat the barrier means with RF energy. Balloon **150**, **150'** is deflated and removed after heating the sealing means. These thermal methods and devices achieve the goal of adhering the sealing means to the AF and NP and potentially other surrounding tissues. The application of heat can further aid the procedure by killing small nerves within the AF, by causing the defect to shrink, or by causing cross-linking and/or shrinking of surrounding tissues. An expander or enlarging means **53** can also be an integral component of barrier **12** inserted within sealing means **51**. After the application of heat, a separate enlarging means **53** can be inserted into the interior cavity of the barrier means to either enlarge the barrier **12** or add stiffness to its structure. Such an enlarging means is preferably similar in make-up and design to those described above. Use of an enlarging means may not be necessary in some cases and is not a required component of this method.

[**0160**] The barrier means **12** shown in **FIG. 25** preferably has a primary curvature or gentle curve along the length of the patch or barrier **12** that allows it to conform to the inner circumference of the AF **10**. This curvature may have a single radius R as shown in **FIGS. 44A and 44B** or may have multiple curvatures. The curvature can be fabricated into the barrier **12** and/or any of its components. For example, the sealing means can be made without an inherent curvature while the enlarging means can have a primary curvature along its length. Once the enlarging means is placed within the sealing means the overall barrier means assembly takes on the primary curvature of the enlarging means. This modularity allows enlarging means with specific curvatures to be fabricated for defects occurring in various regions of the anulus fibrosis.

[**0161**] The cross section of the barrier **12** can be any of a number of shapes. Each embodiment exploits a sealing means **51** and an enlarging means **53** that may further add stiffness to the overall barrier construct. **FIGS. 30A and 30B** show an elongated cylindrical embodiment with enlarging means **53** located about the long axis of the device. **FIGS. 31A and 31B** depict a barrier means comprising an enlarging means **53** with a central cavity **49**. **FIGS. 32A and 32B** depict a barrier means comprising a non-axisymmetric sealing means **51**. In use, the longer section of sealing means **51** as seen on the left side of this figure would extend between opposing vertebra **50** and **50'**. **FIGS. 33A and 33B** depict a barrier means comprising a non-axisymmetric sealing means **51** and enlarger **53**. The concave portion of the barrier means preferably faces nucleus pulposus **20** while the convex surface faces the defect **16**, annulotomy **416**, or access hole **417** and the inner aspect of the anulus fibrosis **10**. This embodiment exploits pressure within the disc to compress sealing means **51** against neighboring vertebral bodies **50** and **50'** to aid in sealing. The 'C' shape as shown in **FIG. 33A** is the preferred shape of the barrier wherein the convex portion of the patch rests against the interior aspect of the AF while the concave portion faces the NP. Used in this manner, the barrier or patch **12** serves to partially encapsulate the nucleus puposus **20** by conforming to the gross morphology of the inner surface of the anulus **10** and presenting a concave or cupping surface toward the nucleus **20**. To improve the sealing ability of such a patch, the upper and lower portions of this 'C' shaped barrier means are positioned against the vertebral endplates or overlying cartilage. As the pressure within the nucleus increases, these portions of the patch are pressurized toward the endplates with an equivalent pressure, preventing the passage of materials around the barrier means. Dissecting a matching cavity prior to or during patch placement can facilitate use of such a 'C' shaped patch.

[**0162**] **FIGS. 34 through 41** depict various enlarging or expansion devices **53** that can be employed to aid in expanding a sealing element **51** within the intervertebral disc **15**. Each embodiment can be covered by, coated with, or cover the sealing element **51**. The sealing means **51** can further be woven through the expansion means **53**. The sealing element **51** or membrane can be a sealer which can prevent flow of a material from within the anulus fibrosis of the intervertebral disc through a defect in the anulus fibrosis. The material within the anulus can include nucleus pulposus or a prosthetic augmentation device, such as a hydrogel.

[**0163**] **FIGS. 34 through 38** depict alternative patterns to that illustrated in **FIG. 33A**. **FIG. 33A** shows the expansion devices **53** within the sealing means **51**. The sealing means can alternatively be secured to one or another face (concave or convex) of the expansion means **53**. This can have

advantages in reducing the overall volume of the barrier means **12**, simplifying insertion through a narrow cannula. It can also allow the barrier means **12** to induce ingrowth of tissue on one face and not the other. The sealing means **51** can be formed from a material that resists ingrowth such as expanded polytetraflouroethylene (e-PTFE). The expansion means **53** can be constructed of a metal or polymer that encourages ingrowth. If the e-PTFE sealing means **51** is secured to the concave face of the expansion means **53**, tissue can grow into the expansion means **53** from outside of the disc **15**, helping to secure the barrier means **12** in place and seal against egress of materials from within the disc **15**.

[**0164**] The expansion means **53** shown in **FIG. 33A** can be inserted into the sealing means **51** once the sealing means **51** is within the disc **15**. Alternatively, the expansion means **53** and sealing means **51** can be integral components of the barrier means **12** that can be inserted as a unit into the disc.

[**0165**] The patterns shown in **FIGS. 34 through 38** can preferably be formed from a relatively thin sheet of material. The material may be a polymer, metal, or gel, however, the superelastic properties of nickel titanium alloy (NITINOL) makes this metal particularly advantageous in this application. Sheet thickness can generally be in a range of 0.1 mm to 0.6 mm and for certain embodiments has been found to be optimal if between 0.003" to 0.015" (0.0762 mm to 0.381 mm), for the thickness to provide adequate expansion force to maintain contact between the sealing means **51** and surrounding vertebral endplates. The pattern may be Wire Electro-Discharge Machined, cut by laser, chemically etched, or formed by other suitable means.

[**0166**] **FIG. 34A** shows an embodiment of a non-axisymmetric expander **153** having a superior edge **166** and an inferior edge **168**. The expander **153** can form a frame of barrier **12**. This embodiment comprises dissecting surfaces or ends **160**, radial elements or fingers **162** and a central strut **164**. The circular shape of the dissecting ends **160** aids in dissecting through the nucleus pulposus **20** and/or along or between an inner surface of the anulus fibrosis **10**. The distance between the left-most and right-most points on the dissecting ends is the expansion means length **170**. This length **170** preferably lies along the inner perimeter of the posterior anulus following implantation. The expander length **170** can be as short as about 3 mm and as long as the entire interior perimeter of the anulus fibrosis. The superior-inferior height of these dissecting ends **160** is preferably similar to or larger than the posterior disc height.

[**0167**] This embodiment employs a multitude of fingers **162** to aid in holding a flexible sealer or membrane against the superior and inferior vertebral endplates. The distance between the superior-most point of the superior finger and the inferior-most point on the inferior finger is the expansion means height **172**. This height **172** is preferably greater than the disc height at the inner surface of the posterior anulus. The greater height **172** of the expander **153** allows the fingers **162** to deflect along the superior and inferior vertebral endplates, enhancing the seal of the barrier means **12** against egress of material from within the disc **15**.

[**0168**] The spacing between the fingers **162** along the expander length **170** can be tailored to provide a desired stiffness of the expansion means **153**. Greater spacing between any two neighboring fingers **162** can further be employed to insure that the fingers **170** do not touch if the expansion means **153** is required to take a bend along its length. The central strut **164** can connect the fingers and dissecting ends and preferably lies along the inner surface of the anulus **10** when seated within the disc **15**. Various embodiments may employ struts **164** of greater or lesser heights and thicknesses to vary the stiffness of the overall expansion means **153** along its length **170** and height **172**.

[**0169**] **FIG. 35** depicts an alternative embodiment to the expander **153** of **FIG. 34**. Openings or slots **174** can be included along the central strut **164**. These slots **174** promote bending of the expander **153** and fingers **162** along a central line **176** connecting the centers of the dissecting ends **160**. Such central flexibility has been found to aid against superior or inferior migration of the barrier means or barrier **12** when the barrier **12** has not been secured to surrounding tissues.

[**0170**] **FIGS. 34B and 34C** depict different perspective views of a preferred embodiment of the expander/frame **153** within an intervertebral disc **15**. Expander **53** is in its expanded condition and lies along and/or within the posterior wall **21** and extends around the lateral walls **23** of the anulus fibrosis **10**. The superior **166** and inferior **168** facing fingers **162** of expander **153** extend along the vertebral endplates (not shown) and/or the cartilage overlying the endplates. The frame **153** can take on a 3-D concave shape in this preferred position with the concavity generally directed toward the interior of the intervertebral disc and specifically a region occupied by the nucleus pulposus **20**.

[**0171**] The bending stiffness of expander **153** can resist migration of the implant from this preferred position within the disc **15**. The principle behind this stiffness-based stability is to place the regions of expander **153** with the greatest flexibility in the regions of the disc **153** with the greatest mobility or curvature. These flexible regions of expander **153** are surrounded by significantly stiffer regions. Hence, in order for the implant to migrate, a relatively stiff region of the expander must move into a relatively curved or mobile region of the disc.

[**0172**] For example, in order for expander **153** of **FIG. 34B** to move around the inner circumference of anulus fibrosis **10** (i.e. from the posterior wall **21** onto the lateral **23** and/or anterior **27** wall), the stiff central region of expander **153** spanning the posterior wall **21** would have to bend around the acute curves of the posterior lateral corners of anulus **10**. The stiffer this section of expander **153** is, the higher the forces necessary to force it around these corners and the less likely it is to migrate in this direction. This principle was also used in this embodiment to resist migration of fingers **162** away from the vertebral endplates: The slots **174** cut along the length of expander **153** create a central flexibility that encourages expander **153** to bend along an axis running through these slots as the posterior disc height increases and decreased during flexion and extension. In order for the fingers **162** to migrate away from the endplate, this central flexible region must move away from the posterior anulus **21** and toward an endplate. This motion is resisted by the greater stiffness of expander **153** in the areas directly inferior and superior to this central flexible region.

[**0173**] The expander **153** is preferably covered by a membrane that acts to further restrict the movement of materials through the frame and toward the outer periphery of the anulus fibrosis.

[0174] **FIG. 36** depicts an embodiment of the expander **153** of **FIG. 33A** with an enlarged central strut **164** and a plurality of slots **174**. This central strut **164** can have a uniform stiffness against superior-inferior **166** and **168** bending as shown in this embodiment. The strut **164** can alternatively have a varying stiffness along its height **178** to either promote or resist bending at a given location along the inner surface of the anulus **10**.

[0175] FIGS. **37**A-C depict a further embodiment of the frame or expander **153**. This embodiment employs a central lattice **180** consisting of multiple, fine interconnected struts **182**. Such a lattice **180** can provide a structure that minimizes bulging of the sealing means **51** under intradiscal pressures. The orientation and location of these struts **182** have been designed to give the barrier **12** a bend-axis along the central area of the expander height **172**. The struts **182** support inferior **168** and superior **166** fingers **162** similar to previously described embodiments. However, these fingers **162** can have varying dimensions and stiffness along the length of the barrier **12**. Such fingers **162** can be useful for helping the sealer **51** conform to uneven endplate geometries. **FIG. 37B** illustrates the curved cross section **184** of the expander **153** of **FIG. 37A**. This curve **184** can be an arc segment of a circle as shown. Alternatively, the cross section can be an ellipsoid segment or have a multitude of arc segments of different radii and centers. **FIG. 37C** is a perspective view showing the three dimensional shape of the expander **153** of **FIGS. 37A and 37B**.

[0176] The embodiment of the frame **153** as shown in FIGS. **37**A-C, can also be employed without the use of a covering membrane. The nucleus pulposus of many patients with low back pain or disc herniation can degenerate to a state in which the material properties of the nucleus cause it to behave much more like a solid than a gel. As humans age, the water content of the nucleus declines from roughly 88% to less than 75%. As this occurs, there is an increase in the cross linking of collagen within the disc resulting in a greater solidity of the nucleus. When the pore size or the largest open area of any given gap in the lattice depicted in **FIGS. 37A, 37B**, and **37**C is between 0.05 mm^2 (7.75×10^{-5} in^2) and 0.75 mm^2 (1.16×10^{-3} in^2), the nucleus pulposus is unable to extrude through the lattice at pressures generated within the disc (between 250 KPa and 1.8 MPa). The preferred pore size has been found to be approximately 0.15 mm^2 (2.33×10^{-4} in^2). This pore size can be used with any of the disclosed embodiments of the expander or any other expander that falls within the scope of the present invention to prevent movement of nucleus toward the outer periphery of the disc without the need for an additional membrane. The membrane thickness is preferably in a range of 0.025 mm to 2.5 mm.

[0177] **FIG. 38** depicts an expander **153** similar to that of **FIG. 37A** without fingers. The expander **153** includes a central lattice **180** consisting of multiple struts **182**.

[0178] **FIGS. 39 through 41** depict another embodiment of the expander **153** of the present invention. These tubular expanders can be used in the barrier **12** embodiment depicted in **FIG. 31A**. The sealer **51** can cover the expander **153** as shown in **FIG. 31A**. Alternatively, the sealer **51** can cover the interior surface of the expander or an arc segment of the tube along its length on either the interior or exterior surface.

[0179] **FIG. 39** depicts an embodiment of a tubular expander **154**. The superior **166** and inferior surfaces **168** of the tubular expander **154** can deploy against the superior and inferior vertebral endplates, respectively. The distance **186** between the superior **166** and inferior **168** surfaces of the expander **154** are preferably equal to or greater than the posterior disc height at the inner surface of the anulus **10**. This embodiment has an anulus face **188** and nucleus face **190** as shown in **FIGS. 39B, 39C** and **39**D. The anulus face **188** can be covered by the sealer **51** from the superior **166** to inferior **168** surface of the expander **154**. This face **188** lies against the inner surface of the anulus **10** in its deployed position and can prevent egress of materials from within the disc **15**. The primary purpose of the nucleus face **190** is to prevent migration of the expander **154** within the disc **15**. The struts **192** that form the nucleus face **190** can project anteriorly into the nucleus **20** when the barrier **12** is positioned across the posterior wall of the anulus **10**. This anterior projection can resist rotation of the tubular expansion means **154** about its long axis. By interacting with the nucleus **20**, the struts **192** can further prevent migration around the circumference of the disc **15**.

[0180] The struts **192** can be spaced to provide nuclear gaps **194**. These gaps **194** can encourage the flow of nucleus pulposus **20** into the interior of the expander **154**. This flow can insure full expansion of the barrier **12** within the disc **15** during deployment.

[0181] The embodiments of **FIGS. 39, 40** and **41** vary by their cross-sectional shape. **FIG. 39** has a circular cross section **196** as seen in **FIG. 39C**. If the superior-inferior height **186** of the expander **154** is greater than that of the disc **15**, this circular cross section **196** can deform into an oval when deployed, as the endplates of the vertebrae compress the expander **154**. The embodiment of the expander **154** shown in **FIG. 40** is preformed into an oval shape **198** shown in **FIG. 40C**. Compression by the endplates can exaggerate the unstrained oval **198**. This oval **198** can provide greater stability against rotation about a long axis of the expander **154**. The embodiment of **FIGS. 41B, 41C** and **41**D depict an 'egg-shaped' cross section **202**, as shown in **FIG. 41C**, that can allow congruity between the curvature of the expander **154** and the inner wall of posterior anulus **10**. Any of a variety of alternate cross sectional shapes can be employed to obtain a desired fit or expansion force without deviating from the spirit of the present invention.

[0182] **FIGS. 40E, 40F**, and **401** depict the expander **154** of FIGS. **40**A-D having a sealing means **51** covering the exterior surface of the anulus face **188**. This sealing means **51** can be held against the endplates and the inner surface of the posterior anulus by the expander **154** in its deployed state.

[0183] **FIGS. 40G and 40H** depict the expander **154** of **FIG. 40B** with a sealer **51** covering the interior surface of the anulus face **188**. This position of the sealer **51** can allow the expander **154** to contact both the vertebral endplates and inner surface of the posterior anulus. This can promote ingrowth of tissue into the expander **154** from outside the disc **15**. Combinations of sealer **51** that cover all or part of the expander **154** can also be employed without deviating from the scope of the present invention. The expander **154** can also have a small pore size thereby allowing retention of a material such as a nucleus pulposus, for example, without the need for a sealer as a covering.

[0184] FIGS. **42**A-D depict cross sections of a preferred embodiment of sealing means **51** and enlarging means **53**. Sealing means **51** has internal cavity **17** and opening **8** leading from its outer surface into internal cavity **17**. Enlarger **53** can be inserted through opening **8** and into internal cavity **17**.

[0185] **FIGS. 43A and 43B** depict an alternative configuration of enlarger **53**. Fixation region **4** extends through opening **8** in sealing means **51**. Fixation region **4** has a through-hole that can facilitate fixation of enlarger **53** to tissues surrounding defect **16**.

[0186] **FIGS. 44A and 44B** depict an alternative shape of the barrier. In this embodiment, sealing means **51**, enlarger **53**, or both have a curvature with radius R. This curvature can be used in any embodiment of the present invention and may aid in conforming to the curved inner circumference of anulus fibrosis **10**.

[0187] **FIG. 45** is a section of a device used to affix sealing means **51** to tissues surrounding a defect. In this figure, sealing means **51** would be positioned across interior aspect **50** of defect **16**. The distal end of device **110'** would be inserted through defect **16** and opening **8** into the interior cavity **17**. On the right side of this figure, fixation dart **25** has been passed from device **110'**, through a wall of sealing means **51** and into tissues surrounding sealing means **51**. On the right side of the figure, fixation dart **25** is about to be passed through a wall of sealing means **51** by advancing pusher **111** relative to device **110'** in the direction of the arrow.

[0188] **FIG. 46** depicts the use of thermal device **200** to heat sealing means **51** and adhere it to tissues surrounding a defect. In this figure, sealing means **51** would be positioned across the interior aspect **36** of a defect **16**. The distal end of thermal device **200** would be inserted through the defect and opening **8** into interior cavity **17**. In this embodiment, thermal device **200** employs at its distal end resistive heating element **210** connected to a voltage source by wires **220**. Covering **230** is a non-stick surface such as Teflon tubing that ensures the ability to remove device **200** from interior cavity **17**. In this embodiment, device **200** would be used to heat first one half, and then the other half of sealing means **51**.

[0189] **FIG. 47** depicts an expandable thermal element, such as a balloon, that can be used to adhere sealing means **51** to tissues surrounding a defect. As in **FIG. 18**, the distal end of device **130** can be inserted through the defect and opening **8** into interior cavity **17**, with balloon **150'** on the distal end device **130** in a collapsed state. Balloon **150'** is then inflated to expanded state **150**, expanding sealing means **51**. Expanded balloon **150** can heat sealing means **51** and surrounding tissues by inflating it with a heated fluid or by employing RF electrodes. In this embodiment, device **130** can be used to expand and heat first one half, then the other half of sealing means **51**.

[0190] **FIG. 48** depicts an alternative embodiment to device **130**. This device employs an elongated, flexible balloon **150'** that can be inserted into and completely fill internal cavity **17** of sealing means **51** prior to inflation to an expanded state **150**. Using this embodiment, inflation and heating of sealing means **51** can be performed in one step.

[0191] **FIGS. 49A through 49G** illustrate a method of implanting an intradiscal implant. An intradiscal implant system consists of an intradiscal implant **400**, a delivery device or cannula **402**, an advancer **404** and at least one control filament **406**. The intradiscal implant **400** is loaded into the delivery cannula **402** which has a proximal end **408** and a distal end **410**. **FIG. 49A** illustrates the distal end **410** advanced into the disc **15** through an annulotomy **416**. This annulotomy **416** can be through any portion of the anulus **10**, but is preferably at a site proximate to a desired, final implant location. The implant **400** is then pushed into the disc **15** through the distal end **410** of the cannula **402** in a direction that is generally away from the desired, final implant location as shown in **FIG. 49B**. Once the implant **400** is completely outside of the delivery cannula **402** and within the disc **15**, the implant **400** can be pulled into the desired implant location by pulling on the control filament **406** as shown in **FIG. 49C**. The control filament **406** can be secured to the implant **400** at any location on or within the implant **400**, but is preferably secured at least at a site **414** or sites on a distal portion **412** of the implant **400**, i.e. that portion that first exits the delivery cannula **402** when advanced into the disc **15**. These site or sites **414** are generally furthest from the desired, final implant location once the implant has been fully expelled from the interior of the delivery cannula **402**.

[0192] Pulling on the control filament **406** causes the implant **400** to move toward the annulotomy **416**. The distal end **410** of the delivery cannula **402** can be used to direct the proximal end **420** of the implant **400** (that portion of the implant **400** that is last to be expelled from the delivery cannula **402**) away from the annulotomy **416** and toward an inner aspect of the anulus **10** nearest the desired implant location. Alternately, the advancer **404** can be used to position the proximal end of the implant toward an inner aspect of the anulus **20** near the implant location, as shown in **FIG. 49E**. Further pulling on the control filament **406** causes the proximal end **426** of the implant **400** to dissect along the inner aspect of the anulus **20** until the attachment site **414** or sites of the guide filament **406** to the implant **400** has been pulled to the inner aspect of the annulotomy **416**, as shown in **FIG. 49D**. In this way, the implant **400** will extend at least from the annulotomy **416** and along the inner aspect of the anulus **10** in the desired implant location, illustrated in **FIG. 49F**.

[0193] The implant **400** can be any of the following: nucleus replacement device, nucleus augmentation device, anulus augmentation device, anulus replacement device, the barrier of the present invention or any of its components, drug carrier device, carrier device seeded with living cells, or a device that stimulates or supports fusion of the surrounding vertebra. The implant **400** can be a membrane which prevents the flow of a material from within the anulus fibrosis of an intervertebral disc through a defect in the disc. The material within the anulus fibrosis can be, for example, a nucleus pulposus or a prosthetic augmentation device, such as hydrogel. The membrane can be a sealer. The implant **400** can be wholly or partially rigid or wholly or partially flexible. It can have a solid portion or portions that contain a fluid material. It can comprise a single or multitude of materials. These materials can include metals, polymers, gels and can be in solid or woven form. The implant **400** can either resist or promote tissue ingrowth, whether fibrous or bony.

[0194] The cannula **402** can be any tubular device capable of advancing the implant **400** at least partially through the anulus **10**. It can be made of any suitable biocompatible material including various known metals and polymers. It can be wholly or partially rigid or flexible. It can be circular, oval, polygonal, or irregular in cross section. It must have an opening at least at its distal end **410**, but can have other openings in various locations along its length.

[0195] The advancer **404** can be rigid or flexible, and have one of a variety of cross sectional shapes either like or unlike the delivery cannula **402**. It may be a solid or even a column of incompressible fluid, so long as it is stiff enough to advance the implant **400** into the disc **15**. The advancer **404** can be contained entirely within the cannula **402** or can extend through a wall or end of the cannula to facilitate manipulation.

[0196] Advancement of the implant **400** can be assisted by various levers, gears, screws and other secondary assist devices to minimize the force required by the surgeon to advance the implant **400**. These secondary devices can further give the user greater control over the rate and extent of advancement into the disc **15**.

[0197] The guide filament **406** may be a string, rod, plate, or other elongate object that can be secured to and move with the implant **400** as it is advanced into the disc **15**. It can be constructed from any of a variety of metals or polymers or combination thereof and can be flexible or rigid along all or part of its length. It can be secured to a secondary object **418** or device at its end opposite that which is secured to the implant **400**. This secondary device **418** can include the advancer **404** or other object or device that assists the user in manipulating the filament. The filament **406** can be releasably secured to the implant **400**, as shown in **FIG. 49G** or permanently affixed. The filament **406** can be looped around or through the implant. Such a loop can either be cut or have one end pulled until the other end of the loop releases the implant **400**. It may be bonded to the implant **400** using adhesive, welding, or a secondary securing means such as a screw, staple, dart, etc. The filament **406** can further be an elongate extension of the implant material itself. If not removed following placement of the implant, the filament **406** can be used to secure the implant **400** to surrounding tissues such as the neighboring anulus **10**, vertebral endplates, or vertebral bodies either directly or through the use of a dart, screw, staple, or other suitable anchor.

[0198] Multiple guide filaments can be secured to the implant **400** at various locations. In one preferred embodiment, a first or distal **422** and a second or proximal **424** guide filament are secured to an elongate implant **400** at or near its distal **412** and proximal **420** ends at attachment sites **426** and **428**, respectively. These ends **412** and **420** correspond to the first and last portions of the implant **400**, respectively, to be expelled from the delivery cannula **402** when advanced into the disc **15**. This double guide filament system allows the implant **400** to be positioned in the same manner described above in the single filament technique, and illustrated in FIGS. **50**A-C. However, following completion of this first technique, the user may advance the proximal end **420** of the device **400** across the annulotomy **416** by pulling on the second guide filament **424**, shown in **FIG. 50D**. This allows the user to controllably cover the annulotomy **416**. This has numerous advantages in various implantation procedures. This step may reduce the risk of herniation of either nucleus pulposus **20** or the implant itself. It may aid in sealing the disc, as well as preserving disc pressure and the natural function of the disc. It may encourage ingrowth of fibrous tissue from outside the disc into the implant. It may further allow the distal end of the implant to rest against anulus further from the defect created by the annulotomy. Finally, this technique allows both ends of an elongate implant to be secured to the disc or vertebral tissues.

[0199] Both the first **422** and second **424** guide filaments can be simultaneously tensioned, as shown in **FIG. 50E**, to ensure proper positioning of the implant **400** within the anulus **10**. Once the implant **400** is placed across the annulotomy, the first **422** and second **424** guide filaments can be removed from the input **400**, as shown in **FIG. 50F**. Additional control filaments and securing sites may further assist implantation and/or fixation of the intradiscal implants.

[0200] In another embodiment of the present invention, as illustrated in FIGS. **51**A-C, an implant guide **430** may be employed to aid directing the implant **400** through the annulotomy **416**, through the nucleus pulposus **10**, and/or along the inner aspect of the anulus **10**. This implant guide **430** can aid in the procedure by dissecting through tissue, adding stiffness to the implant construct, reducing trauma to the anulus or other tissues that can be caused by a stiff or abrasive implant, providing 3-D control of the implants orientation during implantation, expanding an expandable implant, or temporarily imparting a shape to the implant that is beneficial during implantation. The implant guide **430** can be affixed to either the advancer **404** or the implant **406** themselves. In a preferred embodiment shown in **FIGS. 52A and 52B**, the implant guide **430** is secured to the implant **400** by the first **424** and second **426** guide filaments of the first **426** and the second **428** attachment sites, respectively. The guide filaments **424** and **426** may pass through or around the implant guide **430**. In this embodiment, the implant guide **430** may be a thin, flat sheet of biocompatible metal with holes passing through its surface proximate to the site or sites **426** and **428** at which the guide filaments **422** and **424** are secured to the implant **400**. These holes allow passage of the securing filament **422** and **424** through the implant guide **430**. Such an elongated sheet may run along the implant **400** and extend beyond its distal end **412**. The distal end of the implant guide **430** may be shaped to help dissect through the nucleus **10** and deflect off of the anulus **10** as the implant **400** is advanced into the disc **15**. When used with multiple guide filaments, such an implant guide **430** can be used to control rotational stability of the implant **400**. It may also be used to retract the implant **400** from the disc **15** should this become necessary. The implant guide **430** may also extend beyond the proximal tip **420** of the implant **400** to aid in dissecting across or through the anulus **10** proximate to the desired implantation site.

[0201] The implant guide **430** is releasable from the implant **400** following or during implantation. This release may be coordinated with the release of the guide filaments **422** and **424**. The implant guide **430** may further be able to slide along the guide filaments **422** and **424** while these filaments are secured to the implant **400**.

[0202] Various embodiments of the barrier **12** or implant **400** can be secured to tissues within the intervertebral disc

15 or surrounding vertebrae. It can be advantageous to secure the barrier means **12** in a limited number of sites while still insuring that larger surfaces of the barrier **12** or implant juxtapose the tissue to which the barrier **12** is secured. This is particularly advantageous in forming a sealing engagement with surrounding tissues.

[**0203**] **FIGS. 53-57** illustrate barriers **12** having stiffening elements **300**. The barrier **12** can incorporate stiffening elements **300** that run along a length of the implant required to be in sealing engagement. These stiffening elements **300** can be one of a variety of shapes including, but not limited to, plates **302**, rods **304**, or coils. These elements are preferably stiffer than the surrounding barrier **12** and can impart their stiffness to the surrounding barrier. These stiffening elements **300** can be located within an interior cavity formed by the barrier. They can further be imbedded in or secured to the barrier **12**.

[**0204**] Each stiffening element can aid in securing segments of the barrier **12** to surrounding tissues. The stiffening elements can have parts **307**, including through-holes, notches, or other indentations for example, to facilitate fixation of the stiffening element **300** to surrounding tissues by any of a variety of fixation devices **306**. These fixation devices **306** can include screws, darts, dowels, or other suitable means capable of holding the barrier **12** to surrounding tissue. The fixation devices **306** can be connected either directly to the stiffening element **300** or indirectly using an intervening length of suture, cable, or other filament for example. The fixation device **306** can further be secured to the barrier **12** near the stiffening element **300** without direct contact with the stiffening element **300**.

[**0205**] The fixation device **306** can be secured to or near the stiffening element **300** at opposing ends of the length of the barrier **12** required to be in sealing engagement with surrounding tissues. Alternatively, one or a multitude of fixation devices **306** can be secured to or near the stiffening element **300** at a readily accessible location that may not be at these ends. In any barrier **12** embodiment with an interior cavity **17** and an opening **8** leading thereto, the fixation sites may be proximal to the opening **8** to allow passage of the fixation device **306** and various instruments that may be required for their implantation.

[**0206**] **FIGS. 53A and 53B** illustrate one embodiment of a barrier **12** incorporating the use of a stiffening element **300**. The barrier **12** can be a plate and screw barrier **320**. In this embodiment, the stiffening element **300** consists of two fixation plates, superior **310** and inferior **312**, an example of which is illustrated in **FIGS. 54A and 54B** with two parts **308** passing through each plate. The parts **308** are located proximal to an opening **8** leading into an interior cavity **17** of the barrier **12**. These parts **8** allow passage of a fixation device **306** such as a bone screw. These screws can be used to secure the barrier means **12** to a superior **50** and inferior **50'** vertebra. As the screws are tightened against the vertebral endplate, the fixation plates **310**, **312** compress the intervening sealing means against the endplate along the superior and inferior surfaces of the barrier **12**. This can aid in creating a sealing engagement with the vertebral endplates and prevent egress of materials from within the disc **15**. As illustrated in **FIGS. 53A and 53B**, only the superior screws have been placed in the superior plate **310**, creating a sealing engagement with the superior vertebra.

[**0207**] **FIGS. 55A and 55B** illustrate another embodiment of a barrier **12** having stiffening elements **300**. The barrier **12** can be an anchor and rod barrier **322**. In this embodiment, the stiffening elements **300** consist of two fixation rods **304**, an example of which is shown in **FIGS. 56A and 56B**, imbedded within the barrier **12**. The rods **304** can include a superior rod **314** and an inferior rod **316**. Sutures **318** can be passed around these rods **314** and **316** and through the barrier means **10**. These sutures **318** can in turn, be secured to a bone anchor or other suitable fixation device **306** to draw the barrier **12** into sealing engagement with the superior and inferior vertebral endplates in a manner similar to that described above. The opening **8** and interior cavity **17** of the barrier **12** are not required elements of the barrier **12**.

[**0208**] **FIG. 57** illustrates the anchor and rod barrier **322**, described above, with fixation devices **306** placed at opposing ends of each fixation rod **316** and **318**. The suture **18** on the left side of the superior rod **318** has yet to be tied.

[**0209**] Various methods may be employed to decrease the forces necessary to maneuver the barrier **12** into a position along or within the lamellae of the anulus fibrosis **10**. **FIGS. 58A, 58B**, **59**A and **59**B depict two preferred methods of clearing a path for the barrier **12**.

[**0210**] **FIGS. 58A and 58B** depict one such method and an associated dissector device **454**. In these figures, the assumed desired position of the, implant is along the posterior anulus **452**. In order to clear a path for the implant, a hairpin dissector **454** can be passed along the intended implantation site of the implant. The hairpin dissector **454** can have a hairpin dissector component **460** having a free end **458**. The dissector can also have an advancer **464** to position the dissector component **460** within the disc **15**. The dissector **454** can be inserted through cannula **456** into an opening **462** in the anulus **10** along an access path directed anteriorly or anterior-medially. Once a free-end **458** of the dissector component **460** is within the disc **15**, the free-end **458** moves slightly causing the hairpin to open, such that the dissector component **460** resists returning into the cannula **456**. This opening **462** can be caused by pre-forming the dissector to the opened state. The hairpin dissector component **460** can then be pulled posteriorly, causing the dissector component **460** to open, further driving the free-end **458** along the posterior anulus **458**. This motion clears a path for the insertion of any of the implants disclosed in the present invention. The body of dissector component **460** is preferably formed from an elongated sheet of metal. Suitable metals include various spring steels or nickel titanium alloys. It can alternatively be formed from wires or rods.

[**0211**] **FIGS. 59A and 59B** depict another method and associated dissector device **466** suitable for clearing a path for implant insertion. The dissector device **466** is shown in cross section and consists of a dissector component **468**, an outer cannula **470** and an advancer or inner push rod **472**. A curved passage or slot **474** is formed into an intradiscal tip **476** of outer cannula **470**. This passage or slot **474** acts to deflect the tip of dissector component **468** in a path that is roughly parallel to the lamellae of the anulus fibrosis **10** as the dissector component **468** is advanced into the disc **15** by the advancer. The dissector component **468** is preferably formed from a superelastic nickel titanium alloy, but can be constructed of any material with suitable rigidity and strain characteristics to allow such deflection without significant

plastic deformation. The dissector component **468** can be formed from an elongated sheet, rods, wires or the like. It can be used to dissect between the anulus **10** and nucleus **20**, or to dissect between layers of the anulus **10**.

[**0212**] FIGS. **60**A-C depict an alternate dissector component **480** of **FIGS. 59A and 59B**. Only the intradiscal tip **476** of device **460** and regions proximal thereto are shown in these figures. A push-rod **472** similar to that shown in **FIG. 59A** can be employed to advance dissector **480** into the disc **15**. Dissector **480** can include an elongated sheet **482** with superiorly and inferiorly extending blades (or "wings") **484** and **486**, respectively. This sheet **482** is preferably formed from a metal with a large elastic strain range such as spring steel or nickel titanium alloy. The sheet **482** can have a proximal end **488** and a distal end **490**. The distal end **490** can have a flat portion which can be flexible. A step portion **494** can be located between the distal end **490** and the proximal end **488**. The proximal end **488** can have a curved shape. The proximal end can also include blades **484** and **486**.

[**0213**] In the undeployed state depicted in **FIGS. 60A and 60B**, wings **484** and **486** are collapsed within outer cannula **470** while elongated sheet **482** is captured within deflecting passage or slot **474**. As the dissector component **480** is advanced into a disc **15**, passage or slot **478** directs the dissector component **480** in a direction roughly parallel to the posterior anulus (90 degrees to the central axis of sleeve **470** in this case) in a manner similar to that described for the embodiment in **FIGS. 59A and 59B**. Wings **484** and **486** open as they exit the end of sleeve **470** and expand toward the vertebral endplates. Further advancement of dissector component **480** allows the expanded wings **484** and **486** to dissect through any connections of nucleus **20** or anulus **10** to the endplates that may present an obstruction to subsequent passage of the implants of the present invention. When used to aid in the insertion of a barrier, the dimensions of dissector component **480** should approximate those of the barrier such that the minimal amount of tissue is disturbed while reducing the forces necessary to position the barrier in the desired location.

[**0214**] **FIGS. 61A-61D** illustrate a method of implanting a disc implant. A disc implant **552** is inserted into a delivery device **550**. The delivery device **550** has a proximal end **556** and a distal end **558**. The distal end **558** of the delivery device **550** is inserted into an annulotomy illustrated in **FIG. 61A**. The annulotomy is preferably located at a site within the anulus **10** that is proximate to a desired, final implant **552** location. The implant **400** is then deployed by being inserted into the disc **15** through the distal end **558** of the delivery device **550**. Preferably the implant is forced away from the final implant location, as shown in **FIG. 61B**. An implant guide **560** can be used to position the implant **400**. Before, during or after deployment of the implant **400**, an augmentation material **7** can be injected into the disc **15**. Injection of augmentation after deployment is illustrated in **FIG. 61C**. The augmentation material **7** can include a hydrogel or collagen, for example. In one embodiment, the delivery device **550** is removed from the disc **15** and a separate tube is inserted into the annulotomy to inject the flowable augmentation material **7**. Alternately, the distal end **558** of the delivery device **550** can remain within the annulotomy and the fluid augmentation material **554** injected through the delivery device **550**. Next, the delivery device **550** is removed from the annulotomy and the intradiscal implant **400** is positioned over the annulotomy in the final implant location, as shown in **FIG. 61D**. The implant **400** can be positioned using control filaments described above.

[**0215**] Certain embodiments, as shown in **FIGS. 62-66**, depict anulus and nuclear augmentation devices which are capable of working in concert to restore the natural biomechanics of the disc. A disc environment with a degenerated or lesioned anulus cannot generally support the load transmission from either the native nucleus or from prosthetic augmentation. In many cases, nuclear augmentation materials **7** bulge through the anulus defects, extrude from the disc, or apply pathologically high load to damaged regions of the anulus. Accordingly, in one aspect of the current invention, damaged areas of the anulus are protected by shunting the load from the nucleus **20** or augmentation materials **7** to healthier portions of the anulus **10** or endplates. With the barrier-type anulus augmentation **12** in place, as embodied in various aspects of the present invention, nuclear augmentation materials **7** or devices can conform to healthy regions of the anulus **10** while the barrier **12** shields weaker regions of the anulus **10**. Indeed, the anulus augmentation devices **12** of several embodiments of the present invention are particularly advantageous because they enable the use of certain nuclear augmentation materials and devices **7** that may otherwise be undesirable in a disc with an injured anulus.

[**0216**] **FIG. 62** is a cross-sectional transverse view of an anulus barrier device **12** implanted within a disc **15** along the inner surface of a lamella **16**. Implanted conformable nuclear augmentation **7** is also shown in contact with the barrier **12**. The barrier device **12** is juxtapositioned to the innermost lamella of the anulus. Conformable nuclear augmentation material **7** is inserted into the cavity which is closed by the barrier **12**, in an amount sufficient to fill the disc space in an unloaded supine position. As shown, in one embodiment, fluid nuclear augmentation **554**, such as hyaluronic acid, is used.

[**0217**] Fluid nuclear augmentation **554** is particularly well-suited for use in various aspects of the current invention because it can be delivered with minimal invasiveness and because it is able to flow into and fill minute voids of the intervertebral disc space. Fluid nuclear augmentation **554** is also uniquely suited for maintaining a pressurized environment that evenly transfers the force exerted by the endplates to the anulus augmentation device and/or the anulus. However, fluid nuclear augmentation materials **554** used alone may perform poorly in discs **15** with a degenerated anulus because the material can flow back out through anulus defects **8** and pose a risk to surrounding structures. This limitation is overcome by several embodiments of the current invention because the barrier **12** shunts the pressure caused by the fluid augmentation **554** away from the damaged anulus region **8** and toward healthier regions, thus restoring function to the disc **15** and reducing risk of the extrusion of nuclear augmentation materials **7** and fluid augmentation material **554**.

[**0218**] Exemplary fluid nuclear augmentation materials **554** include, but are not limited to, various pharmaceuticals (steroids, antibiotics, tissue necrosis factor alpha or its antagonists, analgesics); growth factors, genes or gene vectors in solution; biologic materials (hyaluronic acid, non-

crosslinked collagen, fibrin, liquid fat or oils); synthetic polymers (polyethylene glycol, liquid silicones, synthetic oils); and saline. One skilled in the art will understand that any one of these materials may be used alone or that a combination of two or more of these materials may be used together to form the nuclear augmentation material.

[0219] Any of a variety of additional additives such as thickening agents, carriers, polymerization initiators or inhibitors may also be included, depending upon the desired infusion and long-term performance characteristics. In general, "fluid" is used herein to include any material which is sufficiently flowable at least during the infusion process, to be infused through an infusion lumen in the delivery device into the disc space. The augmentation material **554** may remain "fluid" after the infusion step, or may polymerize, cure, or otherwise harden to a less flowable or nonflowable state.

[0220] Additional additives and components of the nucleus augmentation material are recited below. In general, the nature of the material **554** may remain constant during the deployment and post-deployment stages or may change, from a first infusion state to a second, subsequent implanted state. For example, any of a variety of materials may desirably be infused using a carrier such as a solvent or fluid medium with a dispersion therein. The solvent or liquid carrier may be absorbed by the body or otherwise dissipate from the disc space post-implantation, leaving the nucleus augmentation material **554** behind. For example, any of a variety of the powders identified below may be carried using a fluid carrier. In addition, hydrogels or other materials may be implanted or deployed while in solution, with the solvent dissipating post-deployment to leave the hydrogel or other media behind. In this type of application, the disc space may be filled under higher than ultimately desired pressure, taking into account the absorption of a carrier volume. Additional specific materials and considerations are disclosed in greater detail below.

[0221] **FIG. 63** is a cross-sectional transverse view of anulus barrier device **12** implanted within a disc **15** along an inner surface of a lamella **16**. Implanted nuclear augmentation **7** comprised of a hydrophilic flexible solid is also shown. Nuclear augmentation materials include, but are not limited to, liquids, gels, solids, gases or combinations thereof. Nuclear augmentation devices **7** may be formed from one or more materials, which are present in one or more phases. **FIG. 63** shows a cylindrical flexible solid form of nuclear augmentation **7**. Preferably, this flexible solid is composed of a hydrogel, including, but not limited to, acrylonitrile, acrylic acid, polyacrylimide, acrylimide, acrylimidine, polyacrylonitrile, polyvinylalcohol, and the like.

[0222] **FIG. 63** depicts nuclear augmentation **7** using a solid or gel composition. If required, these materials can be designed to be secured to surrounding tissues by mechanical means, such as glues, screws, and anchors, or by biological means, such as glues and in growth. Solid but deformable augmentation materials **7** may also be designed to resist axial compression by the endplates rather than flowing circumferentially outward toward the anulus. In this way, less force is directed at the anulus **10**. Solid nuclear augmentation **7** can also be sized substantially larger than the annulotomy **416** or defect **8** to decrease the risk of extrusion. The use of solid materials or devices **7** alone is subject to certain limitations. The delivery of solid materials **7** may require a large access hole **417** in the anulus **10**, thereby decreasing the integrity of the disc **15** and creating a significant risk for extrusion of either the augmentation material **7** or of natural nucleus **20** remaining within the disc **15**. Solid materials or devices **7** can also overload the endplates causing endplate subsidence or apply point loads to the anulus **10** from corners or edges that may cause pain or further deterioration of the anulus **10**. Several embodiments of the present invention overcome the limitations of solid materials and are particularly well-suited for use with liquid augmentation materials **7**. The barrier device **12** of various embodiments of this invention effectively closes the access hole **417** and can be adapted to partially encapsulate the augmented nucleus, thus mitigating the risks posed by solid materials.

[0223] Solid or gel nuclear augmentation materials **7** used in various embodiments of the current invention include single piece or multiple pieces. The solid materials **7** may be cube-like, spheroid, disc-like, ellipsoid, rhombohedral, cylindrical, or amorphous in shape. These materials **7** may be in woven or non-woven form. Other forms of solids including minute particles or even powder can be considered when used in combination with the barrier device. Candidate materials **7** include, but are not limited to: metals, such as titanium, stainless steels, nitinol, cobalt chrome; resorbable or non-resorbing synthetic polymers, such as polyurethane, polyester, PEEK, PET, FEP, PTFE, ePTFE, Teflon, PMMA, nylon, carbon fiber, Delrin, polyvinyl alcohol gels, polyglycolic acid, polyethylene glycol; silicon gel or rubber, vulcanized rubber or other elastomer; gas filled vesicles, biologic materials such as morselized or block bone, hydroxy apetite, cross-linked collagen, muscle tissue, fat, cellulose, keratin, cartilage, protein polymers, transplanted or bioengineered nucleus pulposus or anulus fibrosus; or various pharmacologically active agents in solid form. The solid or gel augmentation materials **7** may be rigid, wholly or partially flexible, elastic or viscoelastic in nature. The augmentation device or material **7** may be hydrophilic or hydrophobic. Hydrophilic materials, mimicking the physiology of the nucleus, may be delivered into the disc in a hydrated or dehydrated state. Biologic materials may be autologous, allograft, zenograft, or bioengineered.

[0224] In various embodiments of the present invention, the solid or gel nuclear augmentation material **7**, as depicted in **FIG. 63**, are impregnated or coated with various compounds. Preferably, a biologically active compound is used. In one embodiment, one or more drug carriers are used to impregnate or coat the nuclear augmentation material **7**. Genetic vectors, naked genes or other therapeutic agents to renew growth, reduce pain, aid healing, and reduce infection may be delivered in this manner. Tissue in-growth, either fibrous (from the anulus) or bony (from the endplates), within or around the augmentation material can be either encouraged or discouraged depending on the augmentation used. Tissue in-growth may be beneficial for fixation and can be encouraged via porosity or surface chemistry. Surface in-growth or other methods of fixation of the augmentation material **7** can be encouraged on a single surface or aspect so as to not interfere with the normal range of motion of the spinal unit. In this way, the material is stabilized and safely contained within the anulus **10** without resulting in complete fixation which might cause fusion and prohibit disc function.

[0225] **FIG. 64** is a cross-sectional transverse view of anulus barrier device **12** implanted within a disc **15** along an inner surface of a lamella **16**. Several types of implanted nuclear augmentation **7**, including a solid cube, a composite cylindrical solid **555**, and a free flowing liquid **554** are shown. The use of multiple types of nuclear augmentation with the barrier **12** is depicted in **FIG. 64**. The barrier device **12** is shown in combination with fluid nuclear augmentation **554**, solid nuclear augmentation **7**, in the form of a cube, and a cross-linked collagen sponge composite **555** soaked in a growth factor. In several embodiments of the present invention, a multiphase augmentation system, as shown in **FIG. 64**, is used. A combination of solids and liquids is used in a preferred embodiment. Nuclear augmentation **7** comprising solids and liquids **554** can be designed to create primary and secondary levels of flexibility within an intervertebral disc space. In use, the spine will flex easily at first as the intervertebral disc pressure increases and the liquids flows radially, loading the anulus. Then, as the disc height decreases and the endplates begin to contact the solid or gelatinous augmentation material, flexibility will decrease. This combination can also prevent damage to the anulus **10** under excessive loading as the solid augmentation **7** can be designed to resist further compression such that the fluid pressure on the anulus is limited. In a preferred embodiment, use of multiphase augmentation allows for the combination of fluid medications or biologically active substances with solid or gelatinous carriers. One example of such a preferable combination is a cross-linked collagen sponge **555** soaked in a growth factor or combination of growth factors in liquid suspension.

[0226] In one aspect of the invention, the nuclear augmentation material or device **7**, **554** constructed therefrom is phase changing, i.e. from liquid to solid, solid to liquid, or liquid to gel. In situ polymerizing nuclear augmentation materials are well-known in the art and are described in U.S. Pat. No. 6,187,048, herein incorporated by reference. Phase changing augmentation preferably changes from a liquid to a solid or gel. Such materials may change phases in response to contact with air, increases or decreases in temperature, contact with biologic liquids or by the mixture of separate reactive constituents. These materials are advantageous because they can be delivered through a small hole in the anulus or down a tube or cannula placed percutaneously into the disc. Once the materials have solidified or gelled, they can exhibit the previously described advantages of a solid augmentation material. In a preferred embodiment, the barrier device is used to seal and pressurize a phase changing material to aid in its delivery by forcing it into the voids of the disc space while minimizing the risk of extrusion of the material while it is a fluid. In this situation, the barrier or anulus augmentation device **12** may be permanently implanted or used only temporarily until the desired phase change has occurred.

[0227] Another aspect of the present invention includes an anulus augmentation device **12** that exploits the characteristics of nucleus augmentation devices or materials to improve its own performance. Augmenting the nucleus **20** pressurizes the intervertebral disc environment which can serve to fix or stabilize an anulus repair device in place. The nucleus **20** can be pressurized by inserting into the disc **15** an adequate amount of augmentation material **7**, **554**. In use, the pressurized disc tissue and augmentation material **7**, **554** applies force on the inwardly facing surface of the anulus augmentation device **12**. This pressure may be exploited by the design of the anulus prosthesis or barrier **12** to prevent it from dislodging or moving from its intended position. One exemplary method is to design the inwardly facing surface of the anulus prosthesis **12** to expand upon the application of pressure. As the anulus prosthesis **12** expands, it becomes less likely to be expelled from the disc. The prosthesis **12** may be formed with a concavity facing inward to promote such expansion.

[0228] In several embodiments, the anulus augmentation device **12** itself functions as nuclear augmentation **7**. In a preferred embodiment, the barrier **12** frame is encapsulated in ePTFE. This construct typically displaces a volume of 0.6 cubic centimeters, although thicker coatings of ePTFE or like materials may be used to increase this volume to 3 cubic centimeters. Also, the anulus augmentation device may be designed with differentially thickened regions along its area.

[0229] **FIG. 65** depicts a sagittal cross-sectional view of the barrier device connected to an inflatable nuclear augmentation device **455**. The barrier device **12** is shown connected via hollow delivery and support tube **425** to an nuclear augmentation sack **455** suitable for containing fluid material **554**. The tube **425** has a delivery port or valve **450** that extends through the barrier device and can be accessed from the access hole **417** after the barrier device **12** and augmentation sack **455** has been delivered. This nuclear and anulus augmentation combination is particularly advantageous because of the ease of deliverability, since the sack **455** and the barrier **12** are readily compressed. The connection of the barrier **12** and the augmentation sack **455** also serves to stabilize the combination and prevent its extrusion from the disc **15**. The nuclear augmentation **7** may be secured to the anulus augmentation prosthesis **12** to create a resistance to migration of the overall construct. Such attachment may also be performed to improve or direct the transfer of load from the nuclear prosthesis **7** through the anulus prosthesis **12** to the disc tissues. The barrier **12** and augmentation **7** can be attached prior to, during, or after delivery of the barrier **12** into the disc **15**. They may be secured to each other by an adhesive or by a flexible filament such as suture. Alternatively, the barrier **12** may have a surface facing the augmentation material **7** that bonds to the augmentation material **7** though a chemical reaction. This surface may additionally allow for a mechanical linkage to a surface of the augmentation material **7**. This linkage could be achieved through a porous attachment surface of the barrier **12** that allows the inflow of a fluid augmentation material **7** that hardens or gels after implantation.

[0230] Alternatively, the anulus augmentation device **12** and nuclear augmentation material **7** may be fabricated as a single device with a barrier **12** region and a nuclear augmentation region **7**. As an example, the barrier **12** may form at least a portion of the surface of an augmentation sack **455** or balloon. The sack **455** may be filled with suitable augmentation materials **7** once the barrier has been positioned along a weakened inner surface of the anulus **10**.

[0231] The sequence of inserting the barrier **12** and nuclear augmentation **7** in the disc can be varied according to the nuclear augmentation **7** used or requirements of the surgical procedure. For example, the nuclear augmentation **7** can be inserted first and then sealed in place by the barrier device **12**. Alternatively, the disc **15** can be partially filled,

then sealed with the barrier device **12**, and then supplied with additional material **7**. In a preferred embodiment, the barrier device **12** is inserted into the disc **15** followed by the addition of nuclear augmentation material **7** through or around the barrier **12**. This allows for active pressurization. A disc **15** with a severely degenerated anulus can also be effectively treated in this manner.

[**0232**] In an alternative embodiment, the nuclear augmentation material **7** is delivered through a cannula inserted through an access hole **417** in the disc **15** formed pathologically, e.g. an anular defect **8**, or iatrogenically, e.g. an anuulotomy **416** that is distinct from the access hole **417** that was used to implant the barrier **12**. Also, the same or different surgical approach including transpsoas, presacral, transsacral, tranpedicular, translaminar, or anteriorly through the abdomen, may be used. Access hole **417** can be located anywhere along the anulus surface or even through the vertebral endplates.

[**0233**] In alternative embodiments, the anulus augmentation device **12** includes features that facilitate the introduction of augmentation materials **554** following placement. The augmentation delivery cannula may simply be forcibly driven into an access hole **417** proximal to the barrier **12** at a slight angle so that the edge of the barrier **12** deforms and allows passage into the disc space. Alternatively, a small, flexible or rigid curved delivery needle or tube may be inserted through an access hole **417** over (in the direction of the superior endplate) or under (in the direction of the inferior endplate) the barrier **12** or around an edge of the barrier **12** contiguous with the anulus **15**.

[**0234**] In several embodiments, ports or valves are installed in the barrier **12** device that permit the flow of augmentation material into, but not out of, the disc space. One-way valves **450** or even flaps of material held shut by the intervertebral pressure may be used. A collapsible tubular valve may be fashioned along a length of the barrier. In one embodiment, multiple valves or ports **450** are present along the device **12** to facilitate alignment with the access hole **417** and delivery of augmentation material. Flow channels within or on the barrier **12** to direct the delivery of the material **554** (e.g. to the ends of the barrier) can be machined, formed into or attached to the barrier **12** along its length. Alternatively, small delivery apertures (e.g. caused by a needle) can be sealed with a small amount of adhesive or sutured shut.

[**0235**] **FIG. 66** is sagittal cross-sectional view of a functional spine unit containing the barrier device unit **12** connected to a wedge-shaped nuclear augmentation **7** device. **FIG. 66** illustrates that the geometry of the nuclear augmentation **7** can be adapted to improve the function of the barrier. By presenting nuclear augmentation **7** with a wedge-shaped or hemicircular profile towards the interior of the intervertebral disc space, and attaching it in the middle of the barrier device **12** between the flexible finger-like edges of the barrier device, the force exerted by the pressurized environment is focused in the direction of the edges of the barrier device sealing them against the endplates. Accordingly, this wedge-shaped feature improves the function of the device **12**. One skilled in the art will understand that the nuclear augmentation material **7** may also be designed with various features that improve its interaction with the barrier, such as exhibiting different flexibility or viscosity throughout its volume. For example, in certain applications, it may be preferable for the augmentation **7** to be either stiff at the interface with the barrier **12** and supple towards the center of the disc, or vice versa. The augmentation **7** can also serve to rotationally stabilize the barrier **12**. In this embodiment, the augmentation is coupled to the inward facing surface of the barrier and extends outward and medially into the disc forming a lever arm and appearing as "T-shaped" unit. The augmentation device **7** of this embodiment can extend from the middle of the disc **15** to the opposite wall of the anulus.

[**0236**] One skilled in the art will appreciate that any of the above procedures involving nuclear augmentation and/or anulus augmentation may be performed with or without the removal of any or all of the autologous nucleus. Further, the nuclear augmentation materials and/or the anulus augmentation device may be designed to be safely and efficiently removed from the intervertebral disc in the event they no longer be required.

[**0237**] While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims.

What is claimed is:

1. A method of closing a defect in an anulus fibrosus of an intervertebral disc, comprising:

inserting a barrier through an opening into a disc; and

positioning said barrier relative to said defect such that said barrier obstructs passage of material from the interior of said disc into said defect.

2. The method of claim 1, wherein said barrier is larger than in area than the defect.

3. The method of claim 1, wherein said barrier is expandable.

4. The method of claim 1, wherein said barrier is expanded from a compressed state after insertion to the interior of the disc.

5. The method of claim 1, further comprising the step of causing the barrier to expand within the intervertebral disc but not inside said defect.

6. The method of claim 1, wherein said opening is spatially separated from said defect.

7. The method of claim 1, wherein said opening is the defect.

8. The method in claim 1, further comprising the step of causing the barrier to expand within the intervertebral disc but not inside said defect.

9. A method of repairing an annular defect in an intervertebral disc comprising:

inserting a first barrier into an interior of the disc and positioning said barrier proximate to an interior aspect of said defect;

positioning a second barrier proximate to the exterior aspect of said defect; and

affixing said first barrier to said second barrier using a fixation device.

10. The method of claim 9, wherein the step of affixing said first barrier to said second barrier using a fixation device comprises affixing said first barrier to said second barrier with a suture.

11. The method of claim 9, wherein the step of affixing said first barrier to said second barrier using a fixation device comprises affixing said first barrier to said second barrier with an anchoring device.

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